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THE DUNNING'S DAM, NEAR SCRANTON, PA.

By E. SHERMAN GOULD, M. Am. Soc. C. E.

READ OCTOBER 17TH, 1894.

WITH DISCUSSION.

The city of Scranton, Pa., with a population of about 85 000, is supplied with water by two private companies, namely, the Scranton Gas and Water Company and the Providence Gas and Water Company. The operations of the latter are confined to the annexed districts of Providence and Green Ridge. By far the greater portion of the city, together with the most important manufacturing establishments, are supplied by the Scranton Gas and Water Company.

At the time of the construction of the works about to be described, the water furnished by this corporation was drawn entirely from Roaring Brook, a large stream emptying into the Lackawanna within the city limits. It was delivered by gravity, the elevation of the distributing reservoir being sufficient to supply all but a few very elevated portions of the city, without pumping.

Prior to 1887 there was but one reservoir, situated some four miles above the city, of a capacity of about 80 000 000 galls. The water consumption was probably in the neighborhood of 6 000 000 or 7 000 000

galls. per day, so there was but little storage. It is true the company controlled the right to the use of the water of Lake Henry, which could be drawn upon in an emergency for about 400 000 000 galls., but, the water-shed of this lake being small, it could not probably be emptied and refilled every year, and was, therefore, not available as a regular supply.

In 1886 a severe drought, during which the reservoir above mentioned was drawn down several feet, and a water famine only averted by opportune rains, gave warning that storage was becoming necessary. The writer was accordingly engaged by Mr. W. W. Scranton, president of the company, in the summer of this year, to design and build a storage reservoir of about 350 000 000 galls. capacity on Oak Run, a small stream emptying into Roaring Brook about 10 miles above the city of Scranton, and draining, above the proposed reservoir, an area of only some $2\frac{1}{3}$ sq. miles.

The dam forming this reservoir presents certain interesting features, but, as they were all repeated upon a much more important scale in the Dunning's Dam about to be described, they will not be mentioned here, further than to state that the dam was completed and the reservoir filled inside of one year from the time of commencing work, and that the actual total cost of the same was $65 392 76, or about 7% inside of the estimate.

The building of the Oak Run reservoir was intended only as a temporary expedient, to provide for immediate contingencies. Prior to and during its construction active steps were taken for the building of another and much larger one on the main stream. As is frequently the case, among all the possible sites for a large dam, one stood out in bold relief as being preferable to all the others, the topography of the valley of Roaring Brook clearly indicating the one most advantageous location for a high dam. The approximate site being thus fixed, the exact position for the axis of the dam was determined by means of an accurate contour map, and subsequently verified on the ground. This map, which was preserved in duplicate, represented the original surface of the ground before any work was done, and thus afforded a ready means of calculating all subsequent excavation and embankment. Test pits were also dug, and a good general idea of the ground obtained before beginning work.

The track of the Delaware, Lackawanna and Western Railroad fol-

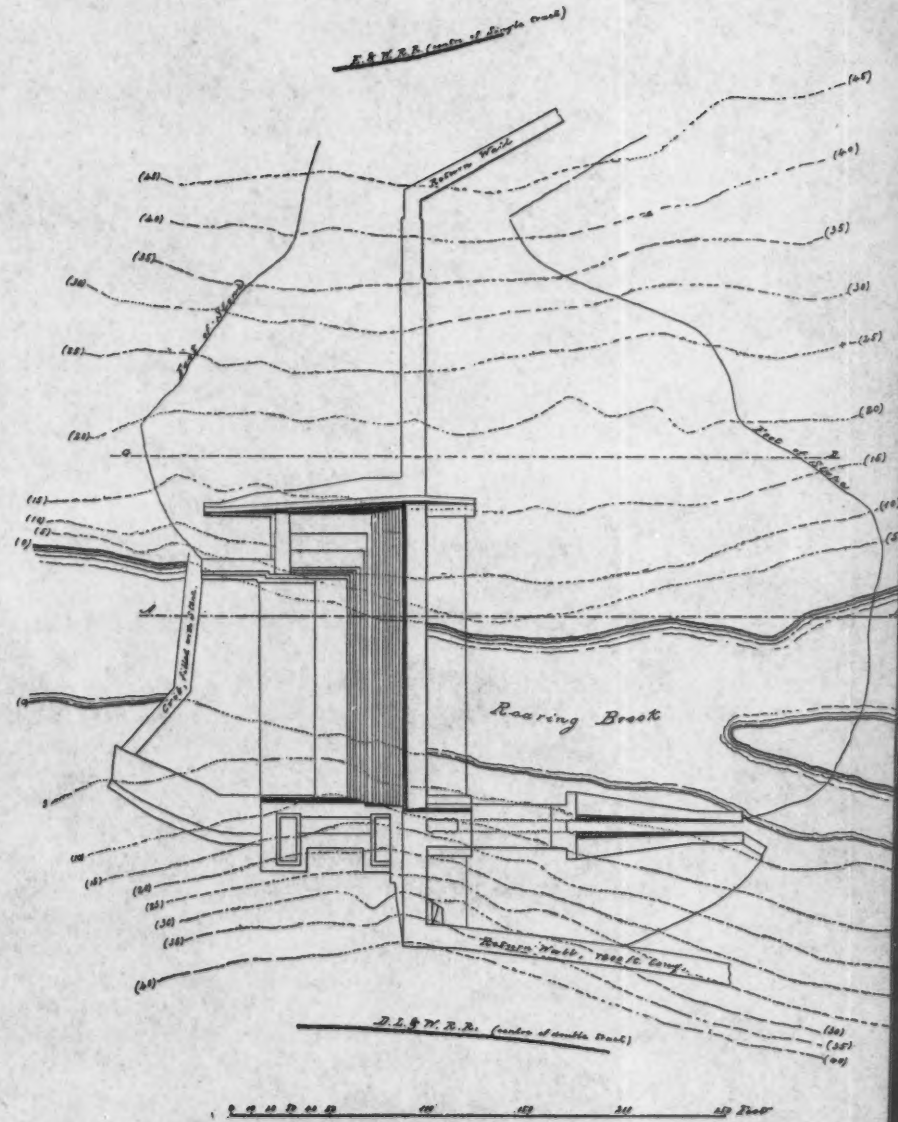
D. L. & W. R. R. (center of single track)
Retaining Wall
Face of Abutment
Face of Abutment
Grade Added with Stone.
Roaring Brook
Retaining Wall, 1902 Ft. Long.
D. L. & W. R. R. (center of double track)
Feet

PLATE LIV.
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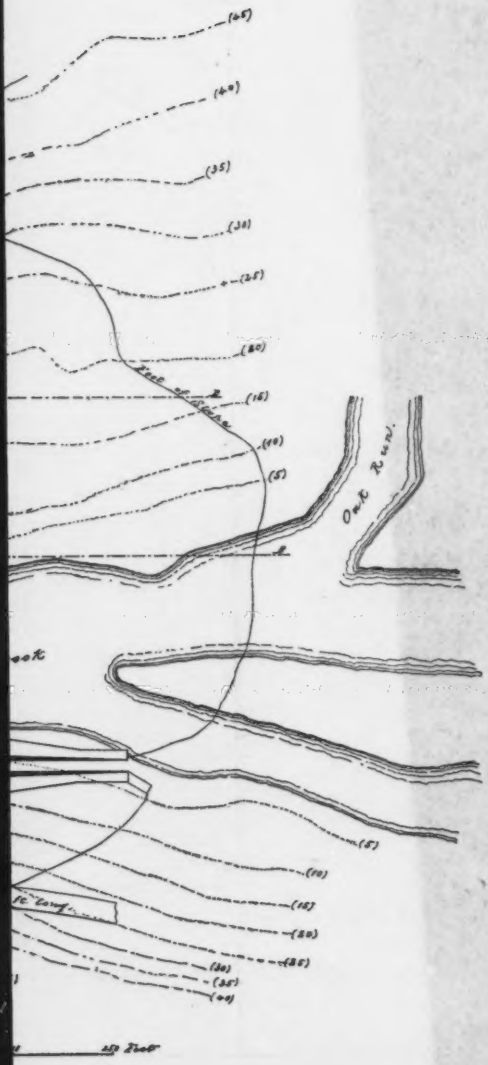
GOULD ON THE DUNNING'S DAM.



lows the left, or southerly, bank of Roaring Brook, through the greater part of its course, and, at the point selected for the dam, approaches very near to the stream. On the right bank the Erie and Wyoming Railroad follows the course of the stream to the point where Oak Run joins it. The track then leaves Roaring Brook to follow the right bank of Oak Run, skirting along the reservoir already mentioned. The location of the dam and of the above-named railroads are shown on Plate LIV.

The nature of the ground at this point was somewhat peculiar, and seems to be characteristic of the streams in this section. On the southerly, or Delaware, Lackawanna and Western side, rock crops out, being apparently the Pocono or Catskill sandstone. This continues to about the middle of the stream, where it breaks off abruptly, the remainder of the bed of the stream and the opposite bank being mostly a stiff clay. This formation, which is shown on Fig. 2, Plate LV, involved the building of the dam half on rock and half on earth, with an abrupt jump from one to the other, the transition point occurring near the center of the spillway.

This outcrop did not extend indefinitely up and down stream from the point selected for the dam. It constituted simply a projecting nose jutting out into the stream, the rock, both above and below, receding considerably from the bank.

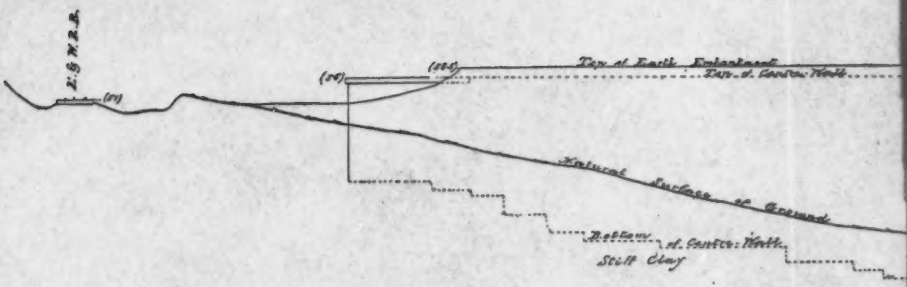
The abrupt breaking off of the rock in the middle of the stream was certainly a very unfavorable circumstance as regards a solid and uniform foundation, but the existence of rock on at least one side was regarded as a great advantage, for it made it possible to get a good and permanent foothold for the tower, and gate chamber, and for the raceway for the discharge pipes, with a great saving of masonry. From the point where the rock broke off, a center wall of masonry was carried along, which formed the core of a heavy earthen embankment upon the northerly, or Erie and Wyoming, side.

In planning the dimensions of the dam, the existence of the two railroads, particularly the Delaware, Lackawanna and Western, presented a serious complication of the problem, and gave rise to the most interesting engineering feature of the work. In order to secure the desired capacity—twelve hundred millions of gallons—it was necessary to raise the lip of the spillway 7 ft. above the level of the Delaware, Lackawanna and Western track at that point. It was impossible, there-

fore, to terminate the dam at the track, and the only way to accomplish the desired end was to carry the main dam up to the necessary height, and then build a side wall to it, running approximately parallel to the track and continuing until the grade of the road, rising at the rate of about 1 in 100, should carry it above the high-water level in the reservoir. This wall ran some 1 200 ft. to a projecting knoll of compact clay loam, into which it was deeply embedded.

The same necessity for a side wall existed upon the opposite bank, but on this side the wall was much shorter, only about 600 ft. long, as the level of the Erie and Wyoming track at this point was about 8 ft. higher than that of the Delaware, Lackawanna and Western. As there was no suitable stopping place for this wall inside the reservoir, it was turned across and under the track, and carried well into the solid bank on the other side.

A somewhat detailed description of the different parts of the work will now be given, taking up afterwards the manner and order in which they were executed. And first to speak of the spillway, which is shown in plan on Plate LIV, and in elevation on Plate LV. This important feature of the dam has a total length of lip of 152.56 ft., and the lip is 5 ft. below the lowest crest of the dam, shown to the right on Fig. 2, Plate LV. The numerous disasters which have occurred from spillways of insufficient capacity, abundantly prove the necessity of great care in fixing their dimensions. In the present case the problem was simplified by the fact that the spillway of the old distributing reservoir, a few miles further down the stream, furnished a basis for calculation. The writer was thus led to adopt the dimensions given above, which have proved to be ample. It will be noticed that on the northerly side—the left-hand side on Fig. 2, Plate LV—the top of the masonry center wall is 1 ft. higher, and the top of the earthen embankment 3½ ft. higher, than the top of the masonry on the southerly or right-hand side, as shown on the same figure. The object of this difference of level was, that if some unprecedented freshet should overpower the discharging capacity of the spillway, aided by the blow-off pipes hereafter to be mentioned, the overflow should take place over that portion of the dam which was of masonry rather than over the earthen embankment. Should such a case occur, the overflow would pass over the gate chamber wall on the right, and the whole length of the side wall along the Delaware, Lackawanna and Western track. This would, of


Natural Surface of Ground
Bottom of Centre Work
Stiff Clay

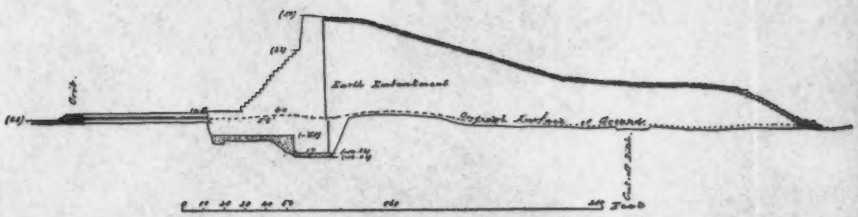

Earth Embankment
Original Surface of Ground

FIG. 3.

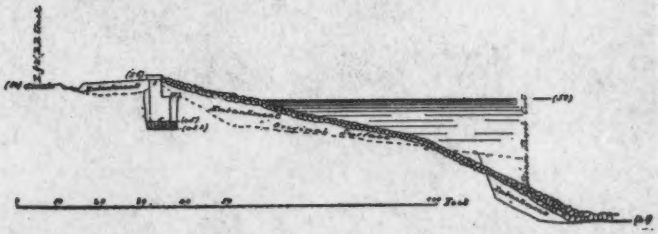


FIG. 4.

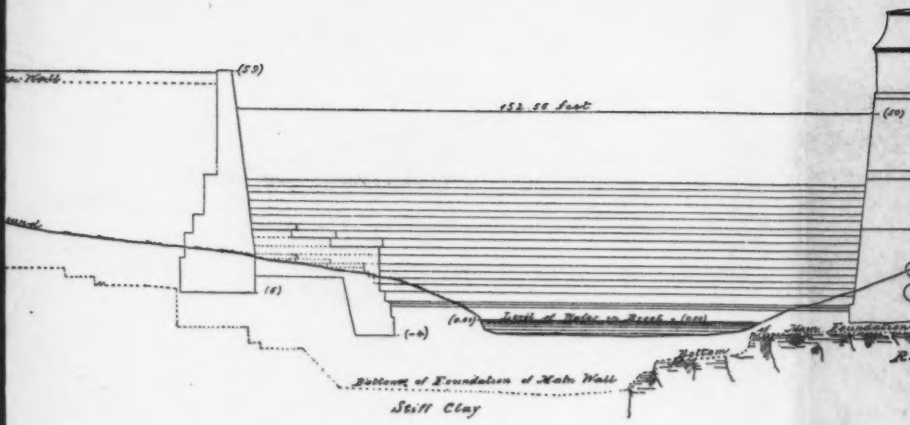


FIG. 2.

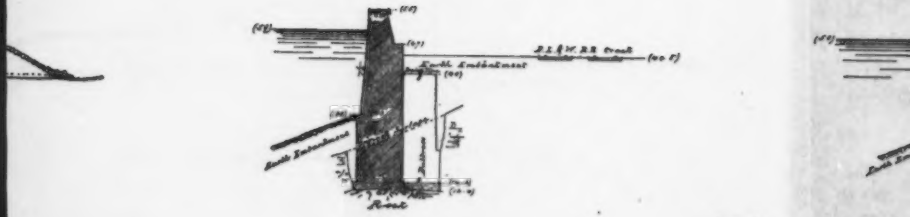
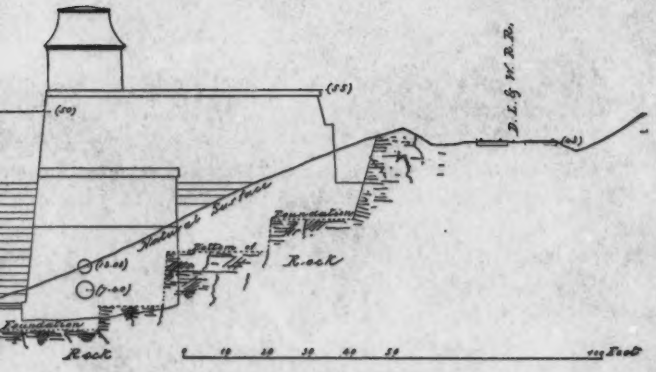


FIG. 5.

FIG. 6.


Rock
Rock
Foundation
Rock
Foundation
Clay & Fine Gravel
South Embankment

course, do great damage to the track, but would insure the more perishable portions of the dam against destruction, and compel a minor disaster to take place instead of a more general one.

A cross-section of the spillway and embankment is shown in Fig. 3, Plate LV, taken through a point where the embankment is the longest, on the line *A–B* of Plate LIV. It will be observed that the masonry is backed up to its full height by a heavy bank of earth. In other words, the inside embankment is continuous over the entire length of the dam, so that in one sense it is an earthen dam with masonry spillway and other adjuncts. The writer is strongly in favor of the earthen backing for all masonry dams. This feature will be referred to again.

This section (Fig. 3) shows the dam as built upon a foundation of stiff clay and fine sand. Where founded upon rock, the concrete was sometimes dispensed with, the surface irregularities being leveled up with spalls.

The sloping front of the spillway was stepped, rather than curved, or simply battered. This was cheaper than a cut stone curved face would have been, and, besides, this manner of handling the overflowing water is preferable to letting it attain a high velocity by sweeping over a free and unobstructed surface. In the writer's opinion it is better to act upon the contrary principle, namely, to destroy its horizontal velocity by a series of falls, by which means the water reaches the apron at the foot of the dam with but little momentum. Of course, either way, the same amount of water per second must finally pass through the channel below the dam, but the difference of level between the top and bottom of the spillway is, in the writer's opinion, better overcome in this manner, although it must be admitted that the question is an open one, on which it is hoped the views of other members may be given.

The construction of the apron is shown also in Fig. 3, Plate LV, and its plan on Plate LIV. This was one of the last pieces of work done, and during the time of construction of the spillway, and previous to its completion, it was repeatedly swept over by floods. The effect of these was to excavate, more or less, the bottom of the stream directly in front of the dam, but to a less extent than was anticipated. In constructing the apron, a timber crib filled with stones was placed at its lower limit. The bottom of the stream was leveled up with dry stone, the excavated portions being first filled up with small stones, and then

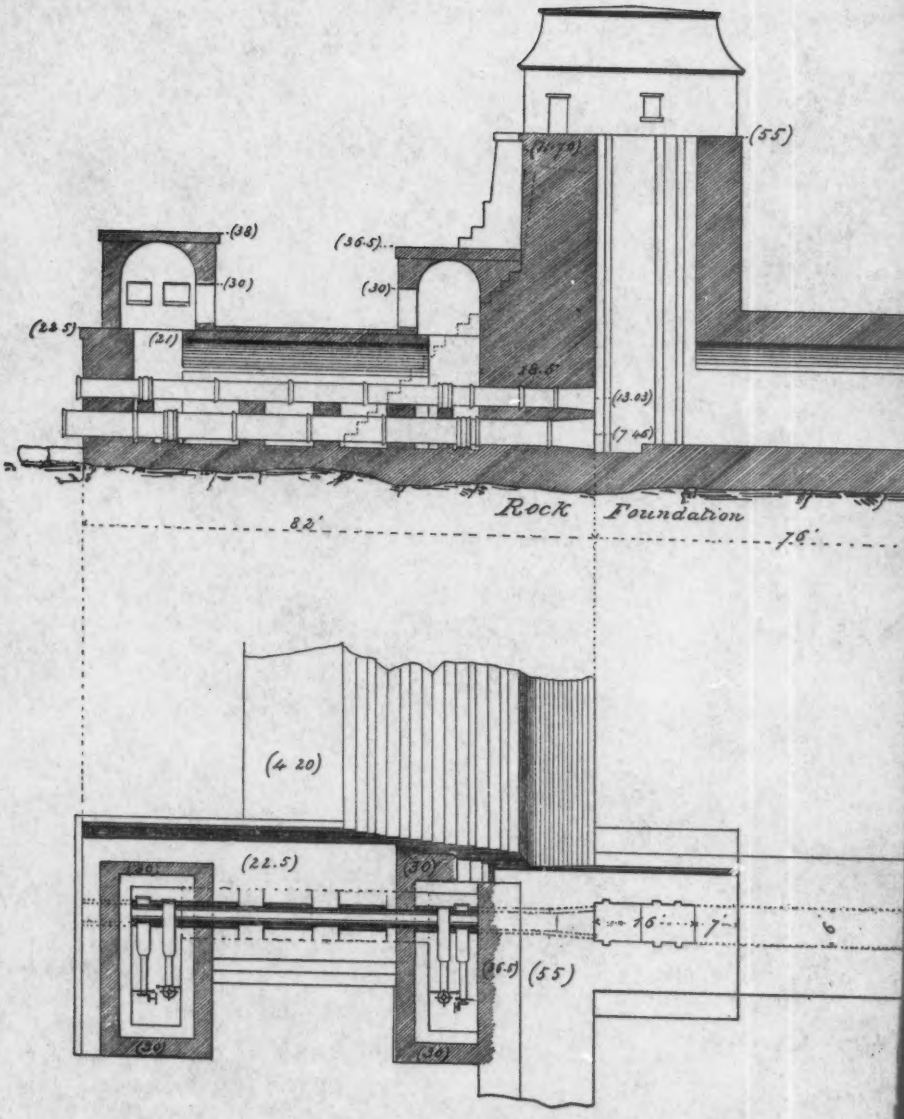
the largest obtainable placed as regularly as possible on the top. The joints of these were packed with spalls, and then a continuous bed of concrete, averaging about 1 ft. in thickness, spread over the dry stone. On the top of the concrete a stone masonry pavement was placed, consisting of heavy blocks bedded in cement mortar. Later on, some additional dry stone rip-rapping was placed below the crib, to protect it and regulate the channel below. The result of the whole has proved to be eminently successful in preventing wash.

The next most important feature of the dam is the gate chamber and its appurtenances. The writer gave this matter, as it merited, the deepest consideration, going over the drawings and modifying them repeatedly before evolving a design which seemed to him to be fully satisfactory.

This part of the work is shown on a small scale in plan, on Plate LIV, and in front elevation on Fig. 2, Plate LV, and in plan and bird's-eye, and in longitudinal section on Plate LVI.

In order to understand clearly this part of the work, it will be necessary to state the objects which it was sought to accomplish. In the first place, it was necessary to have some simple and easily handled means of drawing water from the reservoir when desired, and the means and appliances used must be, besides, not liable to get out of order, still less to break down. Moreover, they should be of capacity sufficient to appreciably relieve the reservoir in case of necessity, even to the extent of nearly or quite emptying it, at least in the dry season, and for this purpose the opening should be located as near as possible to the bottom of the reservoir. In the present case it was also desired to provide means to connect the city supply directly with this reservoir, so that the actual distributing reservoir could be cut off if desired.

The writer has long been convinced that the best and handiest way of drawing and shutting off water from a reservoir is by means of a cast-iron pipe, built into the masonry of the dam (or of the center wall, if it is an earthen dam), and controlled by two gates or stop-cocks, one placed as near to the dam as possible, and the other a certain distance further along. Accordingly there was built in, in this way, a 48-in. cast-iron pipe, as shown on Plate LVI, as low down as possible, and provided with two horizontal gates, of the New York City pattern. This pipe was supported in solid masonry blocks throughout its entire length, reaching from side to side of the pipe gallery, with holes in the


(55)
(38)
(36.5)
(30)
(30)
(22.5)
(21)
(13.03)
(7.46)
Rock Foundation
82'
76'
(4.20)
(22.5)
(30)
(55)
(30)
(30)

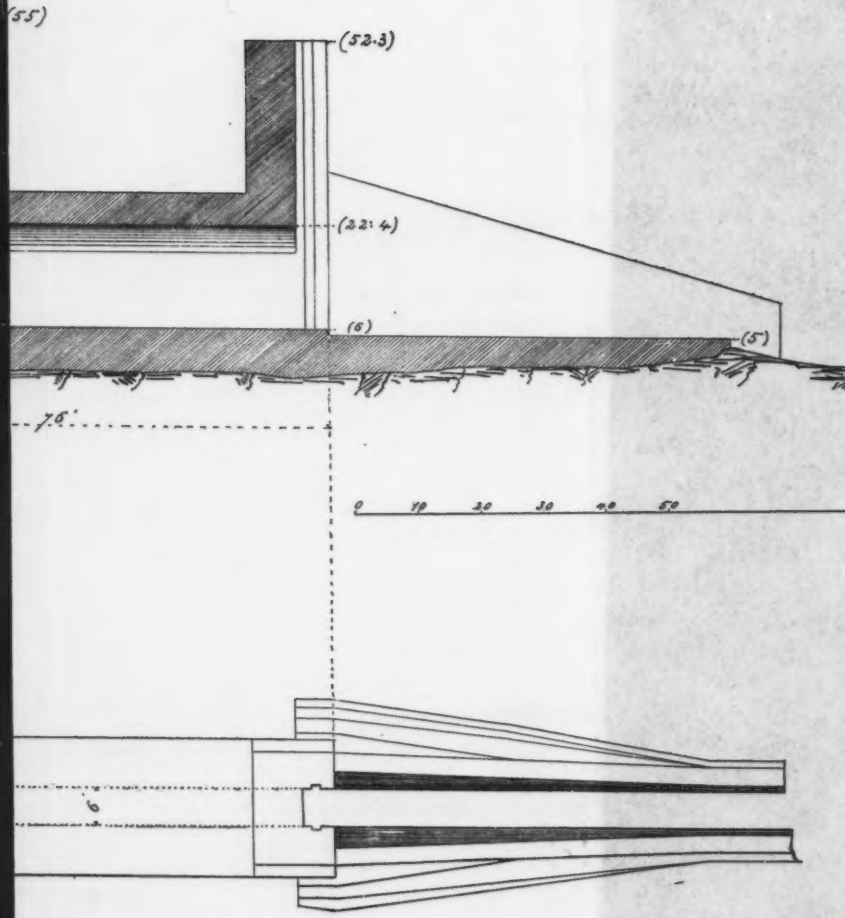

(55)
(52.3)
(22.4)
(6)
(5)
7.6'
0
10
20
30
40
50
6

PLATE LVI.
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100 Feet

bottom, to drain off any water which might otherwise accumulate. Directly over this was a 36-in. pipe destined to be used as a main to the city, if desired. This pipe was also provided with two gates, same pattern and make, and was supported by the same blocks of masonry as the 48-in. pipe, these blocks being continued up to about the axis of the 36-in. pipe. In this way, the 48-in. pipe was, at the points of support, entirely circled with masonry, while the 36-in. was supported in a cradle, extending to half its height. Of the two gates on each pipe, the inner one is to be kept open, or partially open always, and the water turned on or off by means of the lower, or down-stream one. Then, should any accident occur to this latter, the upper one is closed, and the lower one can be got at for repairs. Directly over these gates, in the two gate chambers, wrought-iron eye-beams were built into the walls, so that in case of wishing to handle the gates at any time, blocks and falls could be rigged over them.

Although the two gates above mentioned furnish a pretty good security against accidents, it is necessary to have some additional means of shutting off the water, and of shutting it off in such a way as to permit access to the mouth of the discharge pipe when the reservoir is full. If this case should occur when it became necessary to get at the mouth of the pipe, without emptying the reservoir, it would be obviously necessary to construct some sort of a coffer-dam in front of it, or, as a makeshift, to send down a diver. It would, therefore, be better to construct a permanent coffer-dam at the start, making it a part of the structure, by building a sort of tower containing grooves into which stop plank could be dropped, shutting off the water in a manner which, though not absolutely perfect, has the advantage of being rude and simple, and therefore not liable to get out of order as sluice gates worked with a screw sometimes do.

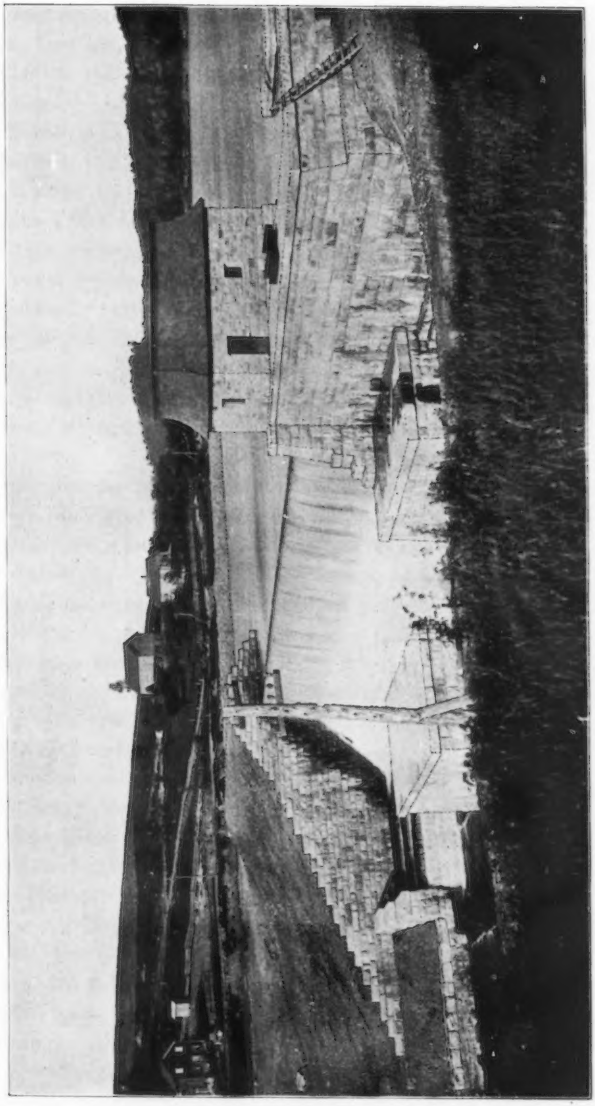
Plate LVI shows such a tower containing two sets of grooves for stop-plank separated by a certain interval which can, if necessary, be packed so as to make the coffer-dam quite water-tight. There is also a third set of grooves intended for the reception of screens should the supply mains ever be connected with the 36-in. pipe.

As has been already stated, the whole of the inside face of the dam was provided with an earthen embankment, not only the northerly part, which consists of a masonry center wall, and an inside and outside bank of earth, but also the southerly half, where a purely masonry

dam was built, and then an embankment of earth added on the inside. There were two reasons for this. Had the inside embankment been confined to the northerly portion, a very heavy and expensive retaining wall projecting into the reservoir would have been needed, costing more than making the bank continuous. A second reason was the conviction, already mentioned, that such a backing is always an advantage, even to a masonry dam. It impedes leakage, and is equivalent to a deepening of the foundation on the water side. A dam built in this way may be regarded as an earthen dam in which the exterior slope of earth has been replaced by an equivalent mass of masonry applied to the front of the center wall. This is the form of dam of medium height which the writer would always recommend when a rock bottom can be found. If the foundation must be upon earth, he would hesitate to adopt it, for he would consider the extra concentration of weight on a smaller surface at the junction of the two different materials, masonry and earth, as disadvantageous, and, besides, would probably feel that the more extended earthen bank would be needed to smother down any percolations from under the center wall which might otherwise show in front of the dam.

The existence of this inside bank made it necessary to study how communication should be established between the water tower and the inside of the reservoir. Building the tower with three sides only, leaving the back open and building two retaining walls, to form an open passage into it, had been thought of. These walls would, however, be very expensive, as has been already intimated, and it was concluded, therefore, to construct an arched gallery running through the bank. It is interesting to note how, in designing, one idea runs into another, so it may be mentioned here that, while studying out the design for retaining or wing walls, the writer considered the possibility of greatly reducing their thickness, and at the same time getting the necessary strength, by throwing at intervals arched braces between them, so that they should be mutually sustaining by being thus connected. It was only a short step further to make these supports continuous, and this led naturally to an arched gallery, such as was actually built.

In order to make this part of the work as complete and efficient as possible, a small tower was also placed at the entrance to the gallery, provided with one set of grooves. In these grooves were placed frames



containing vertical iron bars, some 6 ins. apart, for the purpose of arresting any large floating objects which might otherwise get into the pipes when the water was drawn down. These grooves would also admit of stop-plank being placed in them, by means of which the entire gallery could be emptied of water and inspected while the reservoir was full.

Now, there is a point in regard to these features of the reservoir to which the writer would like to call attention, and that is the way in which they are grouped together. It will be perceived that the main water tower is placed directly against the dam which forms one of its sides, while the northerly side of the tower forms the jaw of the spillway on that side. The gate chamber is also placed in direct contact with the face of the dam, while its side forms the flanking wall of the spillway. In this way not only is material economized, but the structure greatly strengthened at this point by the mutual support of its several parts.

It may here be observed that it is an open question if it would not have been preferable to suppress the outside gallery connecting the two gate-houses, moving the lower one back to the upper and throwing them into one. There would have been some small saving of material, and the design would perhaps have been neater. On the other hand, by the present design, the lower gate is further removed from the dash and spray of the falling water, with perhaps some other advantages. Upon the whole, however, the writer is at present inclined to believe that it would have been a more workmanlike design to have brought both sets of gates under one roof.

Below the lower gate-house, the bank is protected against the wash of the discharge pipes by a heavy retaining wall, curved in plan, and a solid pavement laid in mortar receives the wash from the pipes. This wall and pavement are shown in plan on Plate LIV.

The part of the work which, perhaps, caused the greatest solicitude was the return wall along the Delaware, Lackawanna and Western track, destined to retain the water above the level of the same. The first 200 ft. or so of this wall stood on rock foundation, and, of course, gave rise to no anxiety. After that, however, it left the rocky projection already mentioned, and continued the rest of the way upon earth, mostly clay and fine gravel. The wall was built on the sloping bank lying between the railroad and the stream, in some cases

cutting the foot of the railroad embankment, and thereby giving a good deal of trouble to the contractors, to prevent bringing away the track. It was evident that no fears were to be entertained as to the resistance of the wall against water pressure when the reservoir was full, because it was backed up against the railroad embankment, and could not therefore be overturned nor moved outwardly. The danger to be apprehended was from its being thrown inwardly from the enormous earth pressure against it when the reservoir should be empty, more particularly as the sloping bank upon which it stood would in such case be greatly softened, if not absolutely saturated, from the recent presence of the water. Of course, danger from the softening of the ground on which it stood could be overcome by carrying the foundations down below the bed of the stream, but this would have led to such an enormous increase of expense that the idea was not even entertained. It may here be remarked that the problem was regarded as relieved of a great deal of its gravity by the fact that the possible destruction of the wall could only be looked for when the reservoir was empty; its failure, consequently, could not be accompanied by the awful disasters incident to the bursting of a dam. This was, at least, some comfort, but, even so, the problem remained a very impressive one. A wall was to be built, 1 200 ft. long, exposed for the greater part of its length to the pressure of earth filled in between it and the slope of a railroad embankment. This wall, being built parallel to the stream, naturally would cut off a great deal of the ground and surface water which would otherwise find its way to the lowest point of the valley, so that the bank would be always more or less water-logged. Weepers were, of course, inadmissible, but a drain pipe was placed outside of the wall parallel to it, and between it and the railroad track, so as to intercept at least a portion of the water and conduct it off below the dam.

Fig. 5, Plate LV, shows two sections of this wall, one on rock and the other on earth foundation. It will be seen that the lower part of the wall is vertical on both sides up to elevation (30). At this height an inset was made, and on the water side the wall carried up with a batter of 1 in. to 1 ft. to elevation (54). The coping raises it to (55). The thickness at the top, directly under the coping, was 4.25 ft., and the batter on the side next the railroad 3 ins. to 1 ft. On the water side, wherever the offset at elevation (30) was above the level of the

PLATE LVIII.
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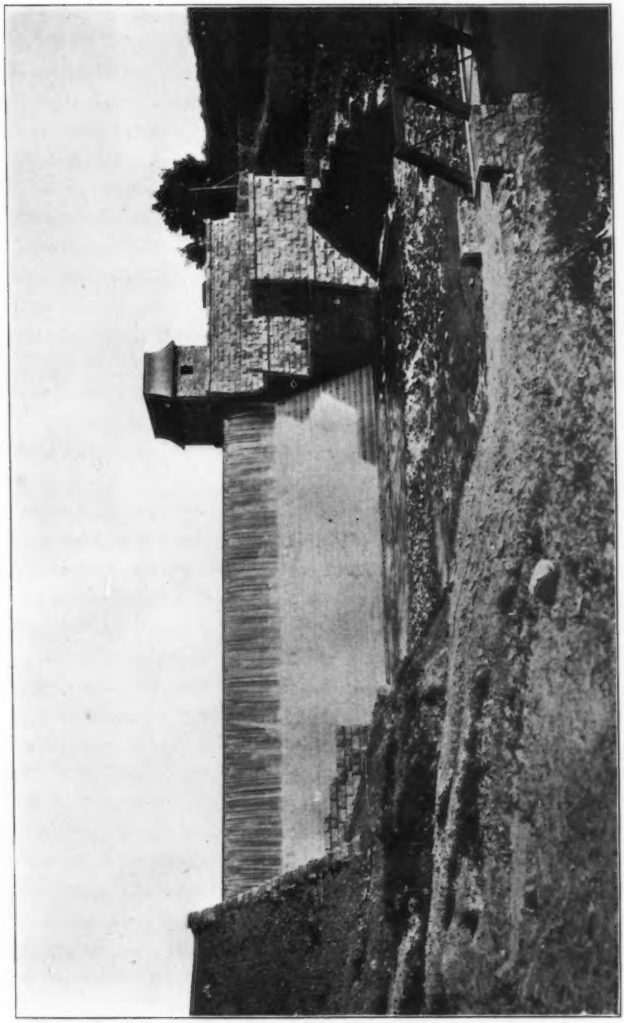


ground, an earthen embankment, rip-rapped, was placed against it at that height, so that the exposed surface of the masonry wall was never more than 25 ft. in height.

It will be readily understood that at times the excavation for this wall gave a good deal of trouble, owing to caving in of the bank. All contractors are apt to take risks in such work and try to get the pit taken out and the masonry built without timbering. In this way a great deal of the excavation has to be taken out twice. In order to economize concrete and to get on as fast as possible, the foundation pits, in earth, were not taken out to the full depth for the full width. The dangerous tendency being, as already mentioned, to overturn into the reservoir, the concrete was given its full depth only under the inside toe about which the wall would tend to turn, as shown in Fig. 5, Plate LV. In the first sections of the wall counter forts were placed at certain intervals, but, largely owing to the delay and labor of excavating for them, particularly when placed on the outside, they were finally done away with, and an additional thickness given to the wall instead.

The center wall calls for no particular mention. It is shown with the embankment in section on Fig. 6, Plate LV. The flat prolongation of the inside embankment shows when the "temporary dam," to be mentioned hereafter, and other provisional filling were incorporated into the permanent work.

As has already been mentioned, the southerly side of the spillway is guarded by the gate chambers and other accessories. On the northerly side it is limited and the water confined by a heavy wing wall, which forms the retaining wall of the exterior earth embankment on that side. It will be remembered that the rock does not extend across the brook, so that this wall and a great part of the spillway rest upon an earthen foundation. Great care was therefore necessary to secure and protect all this part of the work from being undermined. To carry the foundation of the wing wall down below the bed of the stream would have been very expensive; not to do so, and to leave its foot unprotected, would be very dangerous. Accordingly, after going down a certain distance with the foundation, a second or "bench" wall was placed some 25 ft. in front of it, going a little below the bed of the stream, with its top higher than the bottom of the main wall. The intervening space was concreted and paved with heavy blocks of cut

stone, forming a platform over which the water coming from this end of the spillway could wash with safety. This arrangement is shown in Plate LIV, and Fig. 2, Plate LV.

In dam building, the proper order in which to execute the work is always to thoroughly clear and grub the area to be covered by the embankment (particularly the interior one) before any other work is commenced. This being done, all excavated material, when suitable, can be at once deposited in the bank, and just so much work done, once for all, with the advantage to the contractor of its being paid for twice, once as excavation and once as embankment. After this, everything connected with the discharge pipes and blow-off culvert should be got in, because, by choosing a time of drought, it will be frequently possible to divert the entire flow of the stream through these openings, and thus solve the otherwise always perplexing problem of how to get rid of the water when "closing the gap."

In the present case, the first of these operations was only partially carried out, and consequently considerable extra trouble and expense was incurred by the contractors.

In regard to the second point, that of building the discharge pipes, etc., first, the contractors considered it more expedient to commence work on the opposite or north side of the brook, by coffer-damming about half way across the stream, inclosing an area of about 80 x 40 ft. This coffer-dam unfortunately stopped just short of where rock was found on the south side. It would have been a great advantage if it had been extended a little further on, so that the masonry within it could have been at once bonded in with the rock, but the precise position of the rock was not known at the time, so the dimensions of the coffer-dam were largely determined by guess.

The coffer-dam consisted of bents 4 ft. apart, of 6 x 4-in. stuff, sheathed with 2-in. plank. The bents were 4 ft. wide, and the interior space filled in with clay. This coffer-dam was very nearly perfectly tight, and work was carried on very satisfactorily within it.

As regards the nature of the bottom of this excavation, which was destined to contain that part of the spillway and apron, the writer quotes as follows from his journal, September 8th, 1887:

"Have got down to a stratum of quicksand, fine and coarse gravel, which I consider favorable to start the work on, the only objectionable feature being the stones, cobble and gravel. These, however, seem to

be encased in a matrix of fine sand and clay, and the whole forms, I think, a satisfactory and impermeable bottom."

Also the following note in the next day's journal entry:

"Bottom looked satisfactory—fine sand and gravel, quicksand and cobblestones; hard, compact, inelastic—a natural concrete in fact. Am convinced it will make a good foundation, at the depth at which we find it. A bar cannot be forced, by working or driving, more than a foot or so into it. No spouting springs when surface is pierced."

The rock on the south side lay in large flag-like slabs, from 1 to 2 ft. thick, dipping slightly to the north and west, with their partings and beds filled with compact clay. In cutting into this rock, for an excavation of certain width, a great deal of it would be loosened outside of the neat lines, so that much more than was desired would have to be taken away. It was found also impossible to get down to anything more compact and less fissured in its structure, for the entire formation was of the same character. Generally speaking, therefore, when enough of the surface rock had been removed to form a clean face, these large slabs were built upon just as they were, all irregularities being carefully packed with spalls, and care taken to disturb them as little as possible on their natural beds. In working in this rock, powder was very sparingly used; indeed its use was not generally allowed at all, owing to its shattering and dislocating effect.

Work was commenced about August 1st, 1887, and closed for the season December 1st of same year. By that time the foundations were in continuously across the stream.

Work was resumed April 23d, 1888, and in August of same year a "temporary" (so-called) earthen dam was built, to divert the water through the pipes, which by this time were set with their gates. This dam was allowed to form part of the permanent embankment. This process of diverting the water presented great difficulties and many vexatious delays, as the dams put up for the purpose were repeatedly breached. His notes are somewhat scanty in respect to this detail, but the writer thinks that the breach was finally closed by a dry stone wall, through which the water could freely pass while being built. When this wall was finished the water was excluded by placing brush, etc., against it on the inside, and dumping earth behind it, until at last it became tight. For this purpose sand and fine gravel again proved their immense superiority over clay for forming a water-tight

bank. By October 1st the dam was practically tight, and the whole flow of the stream passed through the pipes.

Work on the main dam was stopped for the season November 14th, 1888. A gap was left about 90 ft. long, at elevation of about (27) to provide for freshets. Work was continued on the Delaware, Lackawanna and Western wall till December 10th, when all operations were closed for the season, everything being left in good shape and prepared for any freshet which might occur, and only just in time, for on December 18th, 1888, a heavy freshet did actually take place, the water rising to about elevation (29), sweeping over the unfinished work, gorging both the 48-in. and 36-in. pipes, besides running through the gap in a sheet of water 90 ft. long and 2 ft. deep. The writer estimated the flow to be at the rate of about 1 000 cu. ft. per second, the drainage area being a little over 36 sq. miles. No damage whatever was done to the work.

Work was resumed April 9th, 1889. On the first of June of this year came the awful tidings of the Johnstown disaster, which naturally turned public thought to the safety of the Dunning's dam and reservoir, which was to be of about the same capacity as that at Johnstown, and occupying about the same relative position in regard to the town and steel works. No apprehension was felt by Mr. Scranton, or the writer; but the managers of the Lackawanna Iron and Steel Company requested permission to have the work inspected by experts, and on June 18th, 1889, George S. Greene, Past President M. Am. Soc. C. E., and Charles Macdonald, M. Am. Soc. C. E., inspected it, returning a reassuring report to the company.

The work this season was largely concentrated on the two side dams, one along the Delaware, Lackawanna and Western, and the other along the Erie and Wyoming tracks. The latter is shown in plan in Plate LIV, and in section in Fig. 4, Plate LV. Of these two walls, as already stated, the first was by far the most important. The foundations for this wall were nearly everywhere satisfactory. In almost all cases a pick was needed for each shovel. It may be here stated that this immense wall was throughout a satisfactory piece of work. In only one point was there any noticeable imperfection. This consisted in a small crack in the wall, which developed after it was built and pointed, at about 460 ft. from the angle with the main dam. The opening was widest at top. When first perceived it was about $\frac{1}{2}$ in. in width at the top, running out to nearly nothing further down. Every effort was

made to close this crack, both by pointing it up on the inside when the water in the reservoir permitted, and by dumping sand, cement, sawdust, manure, etc., in front of it, when the reservoir was full, in order that these substances might be sucked into it, with the water which leaked through. It still remained, however, although with time the slight consequent leakage has diminished. The writer has never been able to satisfactorily account for this crack, which did not appear to be due to settlement. He is inclined to believe that it may have been owing to contraction. The wall is a very long one, about 1 200 ft., its length being, however, broken by an offset, and was built very carefully and very compactly, so that it contained no play within itself for contraction. Indeed, if we admit the possibility of expansion and contraction in stone masonry, it is evident that the closer and better built the wall is, the more liable it must be to crack at some point from this cause. The writer would be glad to know if any one has had occasion to observe similar checks in extensive walls upon the construction of which no pains have been spared.

When the reservoir was first filled, considerable leakage was perceptible coming through the wall of the upper gate chamber. It was found that owing to some oversight, the inside of the tower had not been thoroughly raked and pointed. Hay seed, sawdust, cement, etc., were thrown into the tower, and the leakage finally almost or wholly overcome. At present the writer is inclined to doubt if it is wise, in the long run, to immediately rake and point the joints of hydraulic masonry, still less to cover it with plastering, and believes it would be better to turn on the water first, and see how water-tight the wall is of itself, and do the pointing and plastering afterwards. Leaks suppressed by plastering will, of course, break out when the plastering begins to come away (as it surely will sooner or later), and then fears would be excited for the safety of the work.

After the completion of the work, the reservoir was allowed to fill slowly, the rise of the water being regulated by the discharge pipes. On November 15th, 1889, the water was allowed to run over the spillway to the depth of 0.4 ft.

The final estimate was handed in early in February, 1890, as shown on page 404.

A few words regarding the manner in which each of the principal classes of work mentioned in the table was executed may be of interest.

FINAL ESTIMATE OF DUNNING'S DAM, FEBRUARY, 1890.

CLASS OF WORK.	QUANTITIES.	PRICE.	AMOUNT.
	Acres.		
Clearing reservoir site	193.87	$40 00	$7 754 80
	Cu. Yds.		
Rock excavation	6 795.43	1 00	6 795 43
Earth excavation	19 337.70	0 35	6 768 20
Earth embankment	74 804.90	0 35	26 181 72
Cut stone masonry, natural cement	81.20	11 00	893 20
Rubble masonry, natural cement	4 310.62	6 25	26 941 37
Concrete masonry, natural cement	100.10	5 00	500 50
Covering stone, natural cement	84.52	6 25	528 25
Cut stone masonry, Portland cement	858.53	11 50	9 873 09
Rubble masonry, Portland cement	27 219.25	7 00	190 534 75
Concrete masonry, Portland cement	2 742.12	6 00	16 452 72
Brick masonry, Portland cement	148.10	11 00	1 629 10
Covering stone, Portland cement	225.28	7 00	1 576 96
Dry stone wall	1 452.16	3 00	4 356 48
Rip-rap	7 761.65	1 50	11 642 48
			$312 429 05

In clearing the reservoir site, all trees and stumps were cut as nearly as possible level with the ground. That portion of the site which was to be covered by the embankment was grubbed and the sods removed, and, generally speaking, ploughed up before placing the embankment upon it, so as to bond in well with the material forming the embankment.

The embankment was placed, as far as possible, in layers. The material was mostly taken from inside the reservoir, being taken out by a steam shovel, and brought to the foot of the embankment in cars. It was then scraped into place by scrapers, drawn by two horses each. A portion was also placed by wagons having movable bottom boards. It was kept sprinkled while being put in, and the travel of the men, teams and scrapers was sufficient to thoroughly compact it. The material was mostly clay and gravelly loam.

The stone used was mostly the conglomerate found under the coal beds. It was in every respect an admirable material. As a great deal of the work was very thick and massive, some very large stones were used, and, generally speaking, although in drawing up the specifications, the right was reserved to reject all stones over a certain size, considerable latitude was allowed in this respect, only a perfect bedding and jointing of all stones with compact mortar was insisted upon. The masons who executed this work had had a previous train-

ing upon the Oak run dam, and the foremen, as well as the inspector, had by this time thoroughly learned what the writer's requirements for hydraulic masonry were. On commencing work on the Oak run dam stones were constantly raised, after being bedded, and examined, to see that all portions of their beds had come in close contact with the mortar. In working on a thick wall, mortar was thrown in very liberally with the shovel, and all beds kept swimming. When operating this way, there need be no waste of mortar, for the surplus for one stone goes towards the bedding of the next, provided there is a strong gang of masons and a smart foreman to keep the derricks constantly on the swing. On one occasion one foreman, with eight masons and about nine helpers, laid nearly 500 cu. yds. of rubble in 76 hours. This was done with a double drum steam derrick; and, again, another foreman, with seven masons (and probably about eight or nine helpers), laid about 375 cu. yds. in seven days. This represents very rapid work, when the exactions of the engineer and the strictness of the inspection are taken into account.

Concrete was made of hand broken stone, and was hand mixed. The specifications called for proportions of 1, 2 and 3. It was found, however, that this produced an entirely too "fat" mixture, and 1, 2 and 5 was allowed, with good results. When there was running water to contend with, the richer mixture was used, to compensate for wash.

The writer found here, as elsewhere, that 2 cu. yds. of concrete in place, per man per day, counting the entire gang employed, was as much as could be done. The greatest care was exercised in mixing the concrete. A thorough incorporation of ingredients was insisted upon, with thorough tamping. The same care was bestowed upon the mixing of the mortar. No number of turnings was prescribed, but the mixture of sand and cement must be brought to a uniform color before adding the water. Also, a proper consistency and degree of moisture was insisted upon. The proportions were 1 of cement and 2 of sand, when using natural and American Portland cements. When using imported Portland of accepted brands, 1 of cement and 4 of sand was allowed to replace natural cement mortar, and 1 of cement and 3 of sand, to replace American Portland. The testing of the cements the writer attended to personally. When the inspector was not otherwise employed, he also was given tests to make.

Very little masonry or earth work was done on this dam in freezing

weather. While it was in construction, however, the writer was also building another much smaller dam upon another stream—the Stafford Meadow Brook—for the same company. This work had to be begun at once, and was, therefore, carried on during the winter of 1887–88. It was built with American Portland, and a steam boiler, belonging to a pump, was employed for heating the water used in making the mortar, and in steaming the wall and each stone laid in it. In this way every stone was bedded unfrozen. It is probable that the wall froze up each day, and remained frozen till the following spring. It was then examined, found to be all right, and the joints raked out and pointed. What really went on inside of that wall, the writer does not know, and had serious doubts when building it as to whether the mortar would set up after it thawed out, but whatever the process was that went on during that winter and the succeeding spring, the result was perfectly satisfactory.

The writer cannot close this paper without expressing his high appreciation of the manner and spirit in which the work was executed by the contractors, Messrs. Burke Brothers, of Scranton. All the require, ments were faithfully carried out, and they made it a matter of pride to turn out a first-class structure. His thanks are due to his assistant, W. M. Marple, M. Am. Soc. C. E., who had entire charge of laying out the work, which, as will be seen by the drawings, was in many places of a complicated and intricate character. Everything confided to his care was well and accurately done. Mr. J. H. Armstrong was constantly on the work as inspector, going on and off with the whistle, the same as the contractor's foremen. While carrying out instructions to the letter, with skill and intelligence, he had the tact never to antagonize the contractors. It is a pleasure to the writer to bear witness that the eminently successful results achieved in the building of the Dunning's Dam were largely due to the hearty co-operation and good faith of the contractors, and the zeal and fidelity of his assistants.

NOTE.—In all the accompanying drawings, figures inclosed in brackets indicate elevations above or below datum. This is in accordance with the excellent practice of the military engineers in designating "References."

DISCUSSION.

WILLIAM E. WORTHEN, Past President Am. Soc. C. E.—The hearting of the dam which I constructed across the Mohawk, at Cohoes, in 1865, was intended to have a portion of it of large stone, but soon after starting the work it was thought better to make it of quarried stone of sizes that could be readily laid by hand. The work could be made perfectly solid in this way without any chance of voids; the stone could be got more conveniently, and the traveling cranes could be used entirely for the ashlar, with the result that the dam was completed in one season, from the middle of July to about the first day of October, while it was the first intention to have occupied two years.

The dam was of stone, about 1 400 ft. long, an overfall to an old cob dam. The caps were 10 ft. long, some 2 to 3 ft. wide, well bedded in

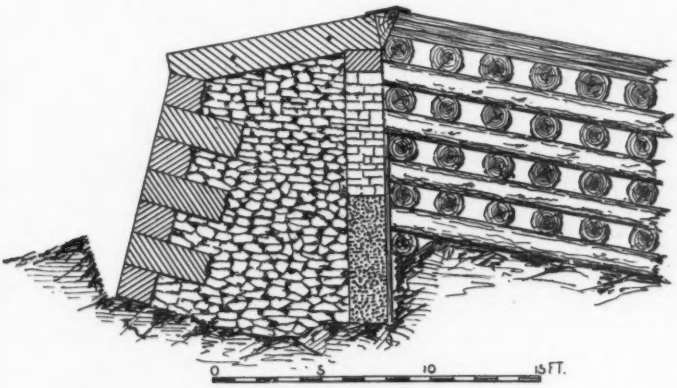


FIG. 1.

cement mortar, dowelled together by galvanized iron dowels; the lateral joint to the depth of 6 ins. was run in sulphur. There was no trouble from expansion, although it was exposed to all extremes of weather, being at times bare, both summer and winter. This sulphur joint kept good till about three years ago when it was re-run as before.

Fig. 1 is a section of the dam in which it will be seen that it supplements an old cob dam, which had settled very much, and of which the overflow had cut deeply into the rock base endangering its stability.

The rock-bed was Hudson River shale to an unknown depth; a shaft was afterwards sunk near the Harmony Mills to more than 1 800 ft. in depth in this strata, and without securing the supply of water for a paper mill for which it was intended.

Plate LIX is a photograph of the dam while under construction, which, with the section, is sufficiently illustrative of the work. At the commencement a board sheathing was nailed to the timbers of the old dam, and made as tight as possible laterally, and at the bottom, on the down-stream side, and at about 20 ins. from the sheathing a close sheet piling was set; care was taken to make the bottom joint tight by what might be termed sausages of dry cement mortar in muslin skins. The channel thus formed was cut into small sections by boards and filled with concrete. The concrete was made in such quantities that the cut-off section could be filled promptly from one batch. A length for dam below the concrete was cut off by piling, mud dams, or the rock itself, and the space was freed from water and cleaned, and then the laying of the stone commenced. As the work progressed the sheet piling was gradually removed and the hearting was connected with the concrete.

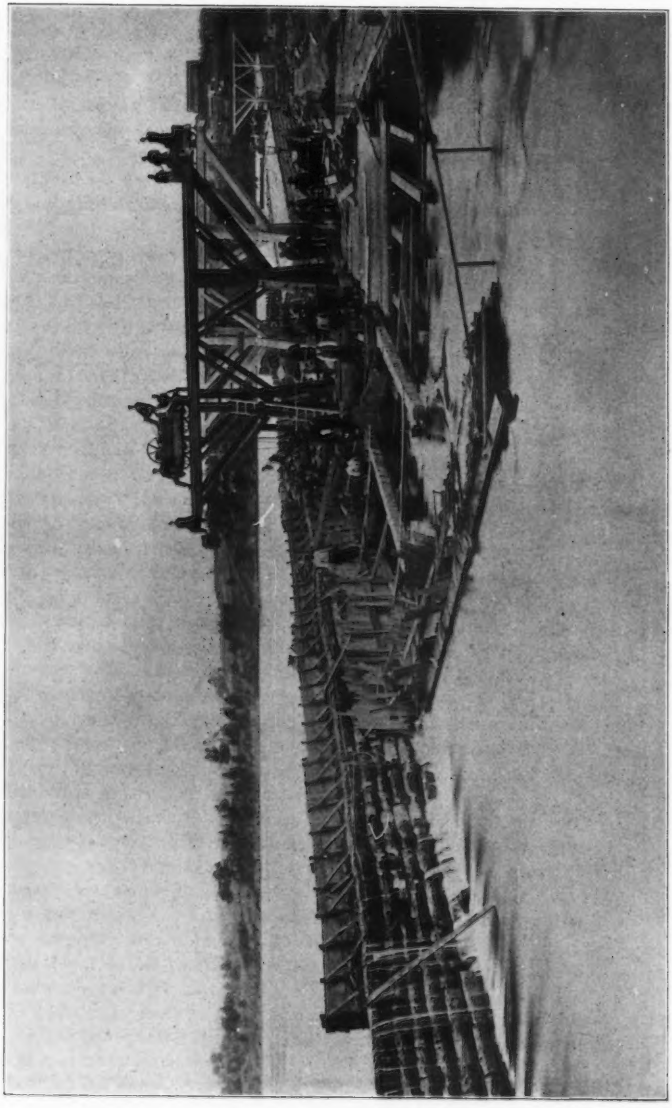
The ashlar was limestone, from Amsterdam, delivered by the Erie Canal, close to the work, and carted down to the river-bed to the travelers. When it was decided to finish the dam in one season, stone of like quality was obtained on the Champlain Canal and delivered at the same place.

The water of the river above the dam was kept off the work by wooden bulkheads or flash-boards, in height and of lengths sufficient to keep the water off the work in progress. Behind this bulkhead the small hearting stock was deposited by boats from a quarry up the river. The space at the top, between the cob and masonry dam, was filled in with a string course of timber, and the upper joints covered by iron plate.

W. R. Hutton, M. Am Soc. C. E.—The conspicuous feature in this dam is the abrupt change in the character of the material upon which it rests, one-half its length being upon rock, the other upon earth, a stiff clay and sand. This construction was a bold departure from recognized principles, and is not to be rashly followed. Its success appears to be due to the section of the masonry and to the embankment on its upper side, the resultant of all the forces acting upon the foundation, passes nearly or quite through the center of the base, giving moderate pressures (about 4 000 lbs. per square foot), uniformly distributed. The building upon such a base seems to have been unavoidable, hemmed in as the reservoir was by a railway on either side, which excluded the alternative of a spillway, excavated in the rock or located entirely upon it.

In the matter of an earth backing to a masonry dam a certain distinction must be made. As the author himself says, this is an earthen dam with a waste weir or spillway of masonry, a construction clearly indicated by the circumstances of foundati on and relatively small height. This mixed method can rarely be applied with economy

PLATE LIX.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXXII, No. 737.
WORTHEN ON COHOES DAM.



and safety to dams of much greater heights than the one under discussion. One hundred feet is probably the limit of height for earth dams. To "high" dams—those over 100 ft. in height—the addition of an embankment on the interior of the reservoir would mean greatly increased expense beyond any compensating advantages.

The sloping front of the waste weir is built in low steps, by which the *vis viva* of the falling water is considerably diminished. This result is highly desirable, and the method has been successfully practiced with crib dams, which, being built of long and tenacious material, are not so much dependent upon superincumbent weight as in the case of a masonry face. In crib dams, however, the steps are long, 6 to 12 ft., and the height much less than the length. They are, in fact, so many aprons upon which the total fall of the water is distributed. In masonry dams with vertical faces and exposed to heavy overflows, it has been deemed unwise to permit any projection on the face. The case here is entirely different, and the author states that the water at the foot of the dam in moderate floods is quite smooth and free from destructive eddies.

The failure of the retaining walls along the railways could occur only by reason of the softening of the ground on which they stand. A broader footing on the inside of the wall would have been an additional protection against overturning.

In the matter of leakage through masonry due to neglect to rake out and point the joints, it has been shown by experiment that cement mortar is not in itself impermeable. Its troweled or burnished surface alone will resist percolation. If the joints are sufficiently regular, they may be rubbed down or burnished when laid. In a wall of rough rubble, the mere raking out the irregular spaces between the stones and filling them with fresh mortar will not do much good, and the chances are that the filling will come out. In the experience of the writer, well-troweled plastering of cement mortar has been efficient and has stood well where not exposed to freezing.

Temperature Cracks in the Long Walls.—There is no doubt that very long concrete walls do crack under variations of temperature. The experience of the Dock Department of New York leads to the making of a transverse joint once in every 150 to 200 ft. of wall. In *Proceedings*, Institution Civil Engineers, for June, 1894, is a description of a service reservoir at Colombo, with concrete walls about 40 ft. high, which cracked under temperature strains, and was only rendered stable by covering it with an embankment of earth.

The author suggests that the two gate chambers might with advantage have been replaced by one. It certainly could have been done at less cost and with greater simplicity. The most simple arrangement is that of a gate-house at the foot of the inner slope of the embankment, closed with stop planks, and having gates at the end of the pipes,

operated from the floor of the gate-house. If more detailed regulation is necessary, a stop-cock vault at the outer base of the embankment will be of easy access. Some of the French engineers have recently invented this arrangement and consider it one of the most important improvements of the day, partly by reason of its simplicity, partly because it renders unnecessary any masonry construction in the body of the embankment, which prevents the uniform compacting of the material. The form is not rare or new in this country. A gallery to carry the pipes under the embankment would seem to be unnecessary. They may be bedded in a mass of concrete, properly formed, with cross-walls. In a gallery it would be preferable to give a continuous support to the pipes, but quite unnecessary to cover them with masonry.

W. H. BALDWIN, M. Am. Soc. C. E.—I think, that as this is a dam calculated to resist a high velocity and strain of water behind it, it is hardly to be compared with the reservoir I am engaged in building, which is merely a distributing reservoir of about 50 000 000 galls. for the water supply of the City of Yonkers, N. Y., and has no overflow.

I have been interested in what the writer has said about a masonry dam. I am engaged in building a partition wall which is intended to divide the reservoir into two compartments. As the water would frequently be at different levels on opposite sides of this wall, there is some solicitude about leakage and percolation; I am awaiting developments in that line. With that exception, I do not think there is any parallelism between the work under my charge at the present time and the work described. Fortunately, in my work all the foundations are on solid rock, so we anticipate no trouble in the way of undermining.

JAMES OWEN, M. Am. Soc. C. E.—The only point that occurs to me is as to the imperviousness of the soil. I presume the result has shown that it was satisfactory in this case.

Also, there is the contingency of the water finding its way through the seams of the rock on one side. In one case where I put up a dam I had great trouble in getting it water-tight on the rock side of the valley. I could keep it tight on the earth side, and I tried coating the rock with cement, but did not find it very satisfactory.

I had one rather curious experience as to porosity of soil. An owner was paid compensation for his land and also for a dam and for his original water right. An impounding dam was built near the same spot, and compensation was afterwards paid for drowning his land below by the water leaking through the natural soil below and around the dam.

About 17 years ago I built a dam of almost pure sand, about 12 ft. high. I found after a period of two years it became absolutely tight, and is still perfectly impervious to water.

KENNETH ALLEN, M. Am. Soc. C. E.—The question of the relative merits of the various profiles for the face of weirs has not, it is thought, been given the same attention as the cross-section required to withstand the static pressures acting on a dam. This is, no doubt, in part due to the fact that the stability of a dam is of the first importance; that this stability is subject to a fairly close approximation by calculation, and that, by this means, a certain economy in construction will result.

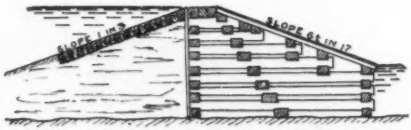


FIG. 1

Timber Crib Dam of the Schuylkill Navigation Company.

In providing for the overflow of dams, on the other hand, more factors have to be taken into consideration, and more liberty is given to the engineer in the introduction of special designs to meet the peculiar local conditions.

Mr. Gould has shown that, with good workmanship, a spillway 40 or 50 ft. in height, discharging water several feet in depth, may be safely built with a stepped face—a profile easy of construction and one which will destroy much of the scouring tendency of the water on leaving it.

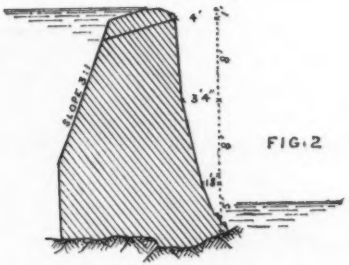


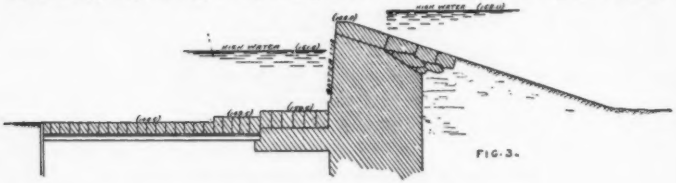
FIG. 2

Macopsin Intake Dam, Newark, N. J., Water Supply.

The impact of a large volume of water falling from the crest of a dam is a powerful agent of destruction, as is made evident by the large number of failures from this cause. The undermining of the dams, or their aprons, at Housatonic, Conn.; Mechanicsville, N. Y.; Holyoke, Mass.; at the Falls of St. Anthony at Minneapolis, and of the dams built by the State of Ohio along the Muskingum River in that State are a few examples of the power of erosion from the overflow of dams, even where the river-bed is of rock.

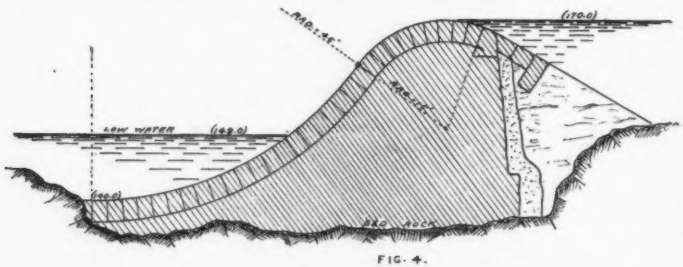
A further objection to the free fall of a large volume of water obtains when periodic vibrations are set up, causing sympathetic vibrations in neighboring buildings, windows, etc. This was sometimes the case with the old Holyoke Dam, and has been observed elsewhere, so that it has sometimes been necessary to draw off the water through the waste gates.

The means taken to prevent the destruction or undermining of spillways vary, depending on the height of the free fall, the depths on the



Dam No. 2.—Sudbury Supply for Boston, Mass.

crest and in the stream below during floods, the presence of floating ice or logs at such times, the character of the bed of the stream and of the masonry composing the face of the spillways. Broadly speaking, there are two ways of accomplishing this: first, by consuming a portion of the *vis viva* of the water through the formation of eddies and other internal motions, and, secondly, by so guiding the falling mass that on reaching the stream bed its motion will be approximately parallel thereto, reducing its scouring action to a minimum.



Lock Raven Dam.—Gunpowder Supply for Baltimore, Md.

This latter method is employed with success in the long, sloping aprons of crib dams of moderate height where a horizontal apron or steps would be subject to injurious impact from ice or logs, or where the fall at the lower end would produce dangerous scour (Fig. 1). It is also employed in masonry dams having a curved profile (Fig. 4); but the increased cost of dressing the stones or the greater quantity of masonry required often prohibits the use of this form. The Vyrnwy Dam for the Liverpool water supply is a good example of this class.

Most masonry dams are built so that the force of the falling water is exerted either directly on the rock bottom of the stream (Fig. 2), on an apron of heavy masonry at the level of the stream bed (Fig. 3), on a series of steps, as in the Dunning's Dam, or on a water cushion of considerable depth below the crest (Fig. 5). To obtain the necessary depth a subsidiary dam below the main structure may be necessary.

The writer would hesitate to suggest any rules to govern the design of a structure where so much depends on the special conditions existing in each case, but from a general consideration of dams, admittedly

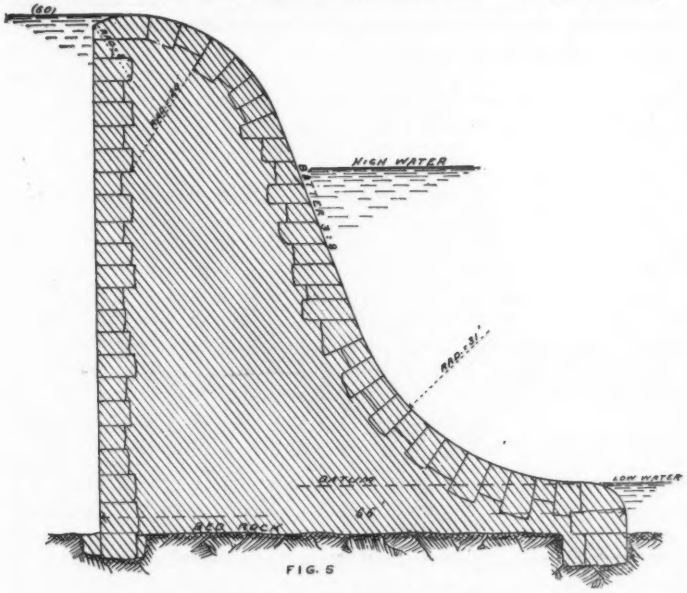


FIG. 5

Colorado River Dam at Austin, Texas.

excellent of their kind, he ventures to draw the following general conclusions:

First.—Where the free fall is not great, say, under 20 ft., an apron will usually be found advisable, unless the stream-bed is of solid rock. When built of crib-work, this apron should have a slope down stream (Fig. 1), but if of masonry it may be horizontal or stepped. A fill of massive boulders below the crest, that is prevented from being washed down stream by a low retaining wall at its lower side, may be used in some cases as a substitute for an apron, as in the Anicut Dam recently built in India.

Second.—For higher dams the fall may be broken by steps or by a water-cushion.

Where steps are used and flood volumes are large, the character of the work should be unusually good, and, with high dams, it would probably be well to give the lower steps an outward slope, as suggested by Rankine, in order to lessen the shock of impact and the dash of water back against the face of the dam.

Third.—In the case of very high dams a saving will be effected by depending largely on a water-cushion. The use of steps to effectually break the fall of a thick sheet from a dam 66 or 80 ft. in height would necessitate an excess of masonry, and unless there were a good depth

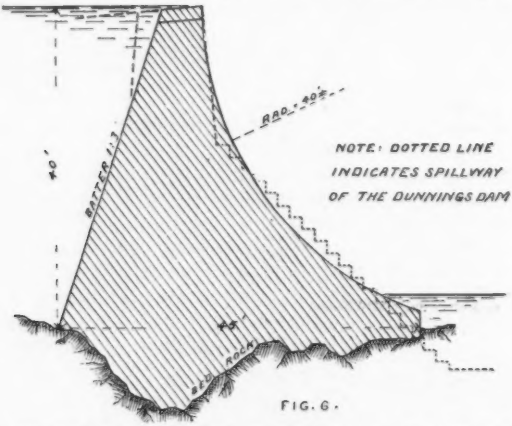


FIG. 6.

North Adams, Mass., Dam.—North Branch of Hoosick River and Dunning's Dam.

of water to receive it, there would, in many cases, be danger of scour.*

Moreover, an attempt to guide the falling sheet by a curved face, as in the Vyrnwy Dam, results in a very heavy section where depths on the crest are great, and, unless founded on rock, will require a wide apron to prevent scour. Where the sheet of water is never very thick, however, a section similar to that of the North Adams Dam (Fig. 6) may be adopted. In many instances a combination of the types indicated will, of course, be best.

Local conditions vary, so that no inflexible rules can be laid down, but the above conclusions are supposed to be correct.

*Some interesting examples of subsidiary dams for the purpose of providing a suitable water-cushion are those for the Pick-Up weir at Vir, India, and for the Turlock and Folsom canal weirs in California—all of them works of considerable magnitude—described by H. M. Wilson, M. Am. Soc. C. E., in the *Transactions*, Am. Soc. C. E., Vol. XXIII, page 217, and Vol. XXV, page 161.

One other point is suggested by Mr. Gould's paper. Is it always safe to assume that the earth fill back of a dam relieves the wall of a portion of the pressure? It undoubtedly does so under favorable conditions, but is it safe to assume this in practice in our calculations? Considering the mass saturated to a semi-fluid condition, the small angle of repose will surely cause a greater pressure than that of water alone.

The question is an interesting and very practical one, which has apparently never been sufficiently settled to result in a uniform practice.

FOSTER CROWELL, M. Am. Soc. C. E.—The point the author has touched on, of carrying his work over from a rock foundation to the earth, is one which comes up, not only in dams, but often in other structures. Some little experience I have had in that direction teaches me to think that, if we leave out of consideration the question of keeping the lower part of the foundation tight against water, and only consider the question of the relative resistance of the earth strata and the rock-bed to vertical pressure, a cushion of sand extending over both for a short distance, of sufficient depth to distribute the pressure, and wide enough to minimize the unit strain on the soft material, is effectual. I have done that with several heavy structures, and have had no trouble whatever, any tendency to crack being distributed over such a length of wall that no harm results. I do not know whether the author of the paper resorted to that in this case or not; and I would like to ask his judgment concerning it, assuming that by benching into the natural formations, and sealing the sand cushion on the side with concrete, the question of percolation can be eliminated.

CHARLES MACDONALD, M. Am. Soc. C. E.—When the author of the paper speaks of coarse sand as being the best, there may be room for a decided difference of opinion in view of the results obtained by what is known as the Danish process, in which sand and cement are first ground together, and then this sand-cement mixed with coarse sand. It has been stated by parties interested in the process that considerable economy in cement may be effected by this combination.

It would certainly seem reasonable to assume that the smaller the void spaces between the particles of sand, the less cement would be required.

R. W. LESLEY, Assoc. Am. Soc. C. E.—If I am not mistaken it was at the time the author was constructing these dams that he made some comparative tests of sand. I thought it was a most ingenious thing to do. My recollection was that the contractors were getting sand from some distant point, and that they wanted to use some sand that was found near the work, and that he took standard sand and tested it with the brand of cement he was using, and then made other tests, with the same cement, of the other two sands referred to, and that as

a result of these experiments it was found that as compared with the standard sand, the sand found near the work was the best one for use. I have often spoken of this matter of testing sand, and I think the author was the first man that ever did it. I thought it was a very ingenious way of determining the question. We have made some experiments with sand and some cement that was sent us and got excellent results, but examining it in a commercial way, the conclusion was that the sand process used in Denmark, where they have no natural cements, and, I am told, very little lime, would be of much more value in that country than here. The admixtures in mortar gave results at 28 days very closely approximating in strength and in cost the results gotten from our natural cements with sand mixtures, and while the results in both cases were excellent, the net cost of a mortar composed of sand cement, the mortar being of a given strength, would not be any cheaper than a mortar with natural cements. The process has some very interesting features, but from the commercial side we could not see where the commercial advantage was in a country where we have such excellent natural cements as we have here. In Denmark, where the natural cements do not exist, it is of commercial value. In the United States, however, natural cements, which with 2 or 3 parts of sand, will be as strong as a commercial sand-cement in equal sand mixtures, can be made cheaper than the sand-cement which requires the washing and drying of the sand and the grinding of the same with Portland cement clinker to fit it for the market.

F. COLLINGWOOD, M. Am. Soc. C. E.—The question of pointing has been referred to in this discussion. There is one very important thing to be remembered in this connection, that it is not safe to do pointing after frosts begin in the fall. The experience on the East River Bridge was, that failure was quite sure to result if this were done. The joints should be absolutely free from dirt, sand, or fragments of mortar, and thoroughly wet before the pointing is inserted. In very high structures still another precaution must be taken. In such cases a sensible compression takes place in the joints, and if the arises be cut sharp, and the pointing done before the masonry above has obtained much height, the compression will surely cause spalling and disfigurement. This was the case on the lower portion of the Washington Monument. In the upper portion the rule was adopted of slightly beveling the horizontal joints for about 1 in. back from the face, and no pointing was done until at least 40 ft. of masonry was built above. On the part thus built no spalling has occurred.

In the Vyrnwy Dam, the pointing was from 3 to 6 ins. deep, and it was kept back ¼ to ½ in. from the face.

ALEXANDER POTTER, Assoc. M. Am. Soc. C. E. (by letter).—There is one point on which the author did not touch in his paper, namely, the practicability of altering the location of the railroads on either side of

the reservoir instead of constructing expensive retaining walls to protect them.

From the rear of the train in passing the point in question there seems to be no unsurmountable engineering difficulty in the way, excepting probably that of grades. The author states, however, that at the dam the grade of the road is but 1 ft. per 100, which is much less than the average grade of the Delaware, Lackawanna and Western from Scranton to a point beyond the dam. The cost of these retaining walls would reconstruct many thousand feet of railroad, and at the same time would remove the danger which the author himself considers within the range of possibility. The writer has no doubt that the author had excellent reasons for not changing the roadbed of these railroads, but thinks that some mention should be made of why it was not done.

In regard to the crack in the wall along the Delaware, Lackawanna and Western tracks a somewhat similar crack occurred in the Beetaloo Dam, described in the *Minutes of Proceedings* Inst. C. E., Vol. CXIII. While stating that three different causes might have produced this defect in the dam, namely, settlement of foundation, contraction due to temperature and earthquake, the engineer in charge advanced the theory "that the shale bands which are wider at the higher levels of the western end of the dam (the cracked end) than at any other point became saturated with water, swelled and lifted the western end upwards and outwards."

The exact nature of the crack and the method of closing it is fully described in the paper referred to.

The author's suggestion that the raking out and pointing of masonry work be left until after the reservoir has been filled is an excellent one, as without doubt many reservoirs remain perfectly tight only as long as the plastering remains in the joints.

The only objection that could be raised is that with the larger reservoirs, when once filled, a strong feeling usually exists among the local people that it will be impossible to fill it again, and so the pointing goes by default.

E. Sherman Gould, M. Am. Soc. C. E.—Replying *seriatim* to those who have discussed my paper, I would say that the details furnished by Mr. Worthen of the construction of the Cohoes Dam are very interesting, and I am glad that some description of this important work has been called forth. The low facing wall of composite construction, shown in the figure as being placed against the old crib structure, differs widely in character, however, from the retaining wall built along the Delaware, Lackawanna and Western track in the Dunning's Dam. This latter wall stands, for a great part of its length, entirely exposed on its top and both sides to the changes of temperature, and is, moreover, lighter in section, so that it can be easily penetrated by heat and

cold. It is, besides, perfectly compact and homogeneous, the only exception to this statement being the fact that the coping is of larger stones than those in the wall immediately below it, and partakes, as coping necessarily must, somewhat of the nature of a superadded and independent piece of work. It may be readily imagined that a structure made up, as the Cohoes wall was, of three or four different classes of work, which it would be impossible to bond together as thoroughly as if composed throughout of only one class, should offer a certain amount of play within itself, and thus take up any expansion or contraction which might occur.

My thanks are due to Mr. W. R. Hutton for his clear appreciation of the peculiar difficulties with which the construction of the dam was surrounded, and of the means adopted to overcome them. The possible softening of the ground on which the long retaining wall stands, referred to by Mr. Hutton, was certainly the most serious cause for apprehension in regard to this feature of the work. The design upon which this wall was built has, however, proved itself to be entirely adequate. The precaution of a transverse joint at certain distances, adopted by the Dock Department of New York, was inadmissible in the present case, and the only thing to do was to found and build the wall as well as possible, and let it take its chances as to expansion and contraction. Perhaps introducing occasional short returns, or offsets, would be advantageous in such walls.

As regards the arrangement of gate-houses referred to by Mr. Hutton as having been adopted by French engineers and others, I am in hopes that a careful study of the plans accompanying my paper may convince others, as I was fully convinced myself, that the system therein shown is greatly superior to the one suggested. It will be seen by the plans and description that the "gate-house" referred to as being placed at the foot of the inner slope of the embankment has been advanced in the Dunning's Dam till it comes into actual contact with and forms part of the main dam itself. By this means access is obtained to the "tower" (as I have termed it) without the need of a bridge or a boat. Great strength is also secured, and the danger of injury or destruction to an isolated tower standing far out in the reservoir from ice and other causes wholly avoided. I called especial attention to this because it seemed to be worthy of careful consideration. It will be seen that the "more detailed regulation" was accomplished in the way referred to by Mr. Hutton. Only I had two sets of stop-cocks instead of one, and two vaults, or gate-houses, which were built separately and connected by a short gallery, which separation I now consider unnecessary, and in another case would certainly make a careful study for a plan uniting the two sets of gates in one gate-house, although such study might, after all, lead me back to my original design.

As Mr. James Owen instances, an impervious dam may be built of pure white sea sand, provided the escape of the sand can be prevented. It is in this way that the dams used for flowing the cranberry bogs in South Jersey are built. A trench is dug through the muck down to the underlying white sand, on each side of which a wall of sods or "floats" is placed, and the interval between these walls filled in with sand of the same character as the subsoil. The result is perfectly satisfactory.

The remarks and examples contributed by Mr. Kenneth Allen are interesting and valuable. I am inclined, on general principles, to prefer a stepped face for the overflow, wherever practicable, for the reasons stated in the paper. Each case, however, should be studied separately in view of the varying conditions. One fact, however, will always remain, and that is that there is safety in a wide and substantial apron extending well beyond the foot of the dam proper, unless it stands upon rock so solid as to render this precaution unnecessary.

As regards the question whether an earthen embankment relieves a wall of a portion of the water pressure, I think there can be no doubt that it does relieve it. The theory sometimes advanced, that the bank should be considered as saturated and semi-fluid, and therefore augmenting rather than diminishing the pressure upon the wall, is best opposed, I think, by the fact that many dams are built wholly of earth, and so far as I know they resist very well, when not overtopped by floods, or penetrated by water following the pipes or culverts running through them. I do not recollect hearing of one failing by slowly melting away from end to end, which would be the case if it become saturated and semi-fluid. I consider, therefore, that a good earthen backing is an element of safety to a masonry dam, although our calculations should never be run so fine as to include an allowance for diminished thrust against the wall, for the object of the bank is rather to prevent leakage, shock and variation of stress, than to lessen pressure.

I did not try the expedient suggested by Mr. Foster Crowell, of covering the junction of the rock and earth foundations with a cushion of sand, with the view of distributing the pressure more evenly. I think that, with proper precautions, a more even bearing might be thus obtained, but I should be very averse, after reaching rock, to cover it over again with a less solid material. I would take what rock I could get, and be thankful for it, and do the best I could with the earth, preferring to have a part better than the whole rather than reduce the whole to a uniform inferiority.

The remarks of Mr. Charles Macdonald apply to a subject brought out in the oral discussion, and not forming part of the paper. I believe that the better results usually obtained with coarse sand are due to the fact that a given volume of coarse sand contains more voids,

and, therefore, more cement than an equal volume of fine sand. If just enough cement were added to a certain volume of coarse sand to exactly fill the voids, to just saturate it, so to speak, it would be found that a smaller quantity of cement would suffice to saturate an equal volume of fine sand, because the volume of the voids would be smaller. A briquette made from the coarse mixture might, therefore, be reasonably expected to "pull" higher than the other, because it would contain more cement.

Mr. R. W. Lesley is correct in the matter of the sand test made to determine the relative value of two different kinds of sand. I doubt, however, if I can claim to be the first to use a testing machine for this purpose, because it seems a very natural thing to do when doubt exists as to the quality of the sand. In the present case, it somewhat oddly happened that the sand which, judged by its appearance, should have been inferior, proved to be superior to the other when actually tested.

There can be no doubt that Mr. Collingwood is perfectly correct in saying that pointing should not be done in freezing weather. It is a difficult job at best, and all conditions should be favorable when it is undertaken.

As Mr. Alexander Potter suggests, the necessity of a retaining wall would have been obviated by shifting the track of the railroad sufficiently up hill, and there would have been no engineering difficulty involved in doing so. Other reasons, however, in the present case, made this expedient appear impracticable, and although it was suggested to me at the time as a possible solution for the problem, the idea was not entertained.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
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RAILROAD SIGNALING.—THE BLOCK SYSTEM.

By JOHN P. O'DONNELL, M. Am. Soc. C. E.

READ AT THE ANNUAL CONVENTION, JUNE, 1894.

WITH DISCUSSION.

It will be the endeavor of the author in the course of this paper to trace the various stages and developments which not only led to the ordinary block working on railways, as now generally in use, but also to the introduction of the interlocking system, which, in combination or union with the block system, seems likely to be the signaling of the future.

In viewing the past history of the block system, it appears strange to us to think that such strenuous opposition was offered to the introduction of even the earliest and most simple forms of block working. The author will endeavor to abridge the records as far as they are obtainable from papers and discussions laid before the various institutions, and from published pamphlets, and compare the general consensus of opinion at the various times and dates of these papers with the various systems in operation at the present date.

The opposition to the introduction of the block system seems parallel to the opposition offered to the earliest railways, and although the pioneers of railways had greater obstacles to overcome than those who have endeavored to persuade the railway companies for their own benefit to adopt the block system, yet improvements on the latter have not been, curiously enough, generally introduced until the stipulated number of years of the life of the various patents have elapsed.

Although this may appear a strange coincidence, yet it can be accounted for by the general hesitation of managers and other responsible officials to enter upon what appeared to them to be an experiment or new departure. The earliest record of the introduction of railways is probably that given in the life of Lord Keeper North, from which it appears tramways were first made use of about the year 1670, for transporting coal from the mines near Newcastle-on-Tyne to the place of shipment. These at first consisted of wooden rails or trams imbedded in the road, to which a second wooden rail was afterwards added, to facilitate repairs and renewals; and these wooden rails were later covered with malleable iron to reduce friction. This last advance was made about the year 1716.

In approximately another hundred years the locomotive steam engine was in use, and railways as now understood were inaugurated with the opening of the Stockton and Darlington Railway on the 27th of September, 1825. It will be observed that something like one hundred and fifty years were absorbed in obtaining the most out of the introduction of the tramway in 1670, and that improvements were slow to be adopted.

Since 1825, the locomotive and the track have remained substantially the same, and the author will endeavor to trace a parallel in the block working of railways, the several stages of improvements and the final result being a little more than an amplification of the devices and ideas laid down in the initial stages. The railroads in their infancy met with great opposition; survey parties went out armed, and often during the night, and Mr. Vignoles, the celebrated engineer, tells how he was arrested while making a moonlight survey and brought before a magistrate (Mr. Bradshaw) on a pretended charge of night poaching.

Mr. Vignoles, in his address to the Institution of Civil Engineers (England), in 1870, mentions this fact, and expresses his belief that

the acquaintance (and subsequently the assistance) of Mr. Bradshaw, brought about in the manner above cited, assisted largely in overcoming the opposition on the part of the Marquis of Stafford and his family to the Liverpool and Manchester Railway.

As the number of trains on railways became larger, it was recognized that it was necessary to establish some kind of system to minimize the risk of collisions from their regular working of trains. The first idea suggested was to allow an interval of time to elapse between the passing of trains at given points, generally, for the sake of convenience, the stations; and, singularly enough, most American lines have not advanced beyond this.

It might here be pertinent to ask the following questions:

WHAT IS THE BLOCK SYSTEM?

WHAT IS THE INTERLOCKING SYSTEM?

WHAT IS THE UNION OF THE LOCK AND BLOCK SYSTEMS?

WHAT IS AN AUTOMATIC BLOCK SYSTEM?

Taking these questions in their order, the block system, as we understand the words, means maintaining a space interval between trains on the same pair of rails. For space intervals substitute "block" or "section," and we have it that a clear block or section, or, as the American Railroad Association puts it, "a length of track of defined limits," is maintained between trains. The American Railroad Association in its rules has not defined "the defined limit," and as this appears an important question, and one that has led to some discussion, perhaps the author may be excused in stating what appears to him to be the true definition of a block section. A block section is the whole of the track from the most advanced signal in a section to the most advanced signal in the section ahead. Briefly, it is the whole of that part of the railroad on which visual signals will, if obeyed, prevent the entrance of a train into the section ahead.

The object of the block system in maintaining an interval of space between trains is to prevent collisions, and Dr. Johnson defines the word collision as an act of "striking together"; the word together sums up the situation, for in order to effect a collision two bodies (frequently moving at high velocities) must be brought into contact with each other. It clearly requires little reasoning that a collision cannot occur with one train only (such train to be provided with automatic brakes, and assuming their working is correct); and it

further follows, by a parity of reasoning, that if the next following train on the same rails is always kept a length of track of "defined limits" apart from the preceding train, the act of striking together (as Dr. Johnson puts it), or collision, of the two trains, cannot under any circumstances occur.

Next, what is an interlocking system? An interlocking system is intended to prevent conflicting switches from being opened at the same time, conflicting signals from being at "safety" at the same time, and conflicting signals and switches from being operated at the same time. The interlocking system is distinguished from the block system in so far that it is intended to provide safety only in the section in which it is applied. A block system by itself is of considerable value where no switches are connected with the passenger roads. Again, an interlocking system, as previously stated, affords safety in its own section. Neither one is complete without the other, even where the two are separately installed. The legitimate amount of safety which the public has a right to expect is not afforded.

This leads us to the third question, what is meant by the union of the lock and block systems? The union of the lock and block systems is the interlocking, or interdependence or amalgamation, of the block system as a whole and the interlocking system as a whole. Here it might be well to ask, what result does the present so-called lock and block system give us? For a block system, pure and simple, a home signal and a distance signal must be provided; but, for the purpose of this third question, let us suppose a starting signal is added. This, or its operating lever, is electrically controlled by the section in advance in any of the known lock and block systems. We, therefore, do not derive any substantial benefit from the interlocking system, for there is practically no interlocking in the ordinary sense of the word included in this combination. There is electrical control, certainly, but the advantages of the mechanical interlocking of switch and signal levers is not attained.

What is an automatic block system? The American Railroad Association defines it as a system which is self-operative, whether by mechanical, electrical, pneumatic, or other device. The meaning is clear, but it may be asked, is it self-operative? Does not the train command the section, and itself actuate all the signals? It would appear that strictly speaking, the word "automatic" in this application is a

misnomer. Would it not be better to call it "non-manual" or "train-operating block system"? Any power system, whether mechanical, electrical, pneumatic or hydraulic, may be classed as "manual." The difference is between those that depend upon human agency for the initial operation, and those that do not. The author begs leave to dissent from the American Railroad Association's description of a "home block signal." The author, having raised ample matter for discussion, will now give a retrospective sketch of block working.

In December, 1839, Messrs. Cooke & Wheatstone induced the Great Western Railway to telegraph the arrival and departure of their trains from station to station between Paddington, West Drayton and Hanwell. In 1841 the same gentlemen introduced separate instruments for signaling the trains each way, these instruments showing at a glance whether the line was "clear" or "blocked." These instruments were provided with pins to hold the needles over to either side so that the needle would show "line clear" or "line blocked," as desired; practically, so far as the result aimed at is concerned, this remains the accepted system of to-day in Great Britain. Bells were also added, and as early as 1841 the principle of the block system of the present day was established.

The great credit of introducing the block system, as it is now understood and worked, is due to Sir William Fothergill Cooke, who, as Mr. Cooke in 1842, published his pamphlet entitled "Telegraphic Railways," in which, specifically, the leading principles of the block system were explained.

It is curious in following the opening of this pamphlet to read that Sir William Cooke had two objects in publishing it. The first was—

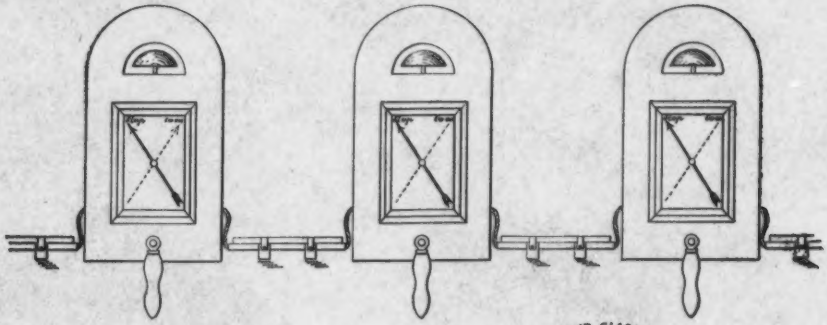
"To add to the safety and efficiency of railway communication, by means not more but less expensive than those now adopted" (1842). The second was "to overcome some objections to the formation of auxiliary single lines, by suggestions calculated to give them the safety and efficiency supposed to be exclusively within the reach of double lines." Sir William Cooke states that: "It is proposed to accomplish these objects by the electric telegraph, the application of which is, it is hoped, clearly explained in the subjoined statement." Further he says that: "It may be considered that the maximum degree of safety and efficiency attainable by subsidiary regulation is already secured on the great double lines of railway," and that "to the comparatively high degree of safety now obtained in railway traveling (1842) depending then, as I have said, upon the vigilance and punctuality in the conduct

of the trains, it is proposed to superadd a physical certainty of their relative places on the line at any moment."

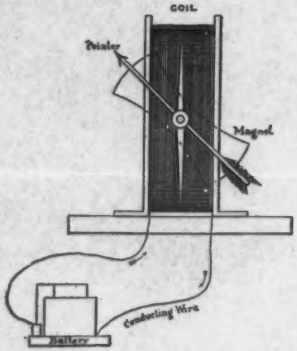
Sir William Cooke, in the course of his paper, described the principles and action of the instruments on the Blackwall Railway, as follows:

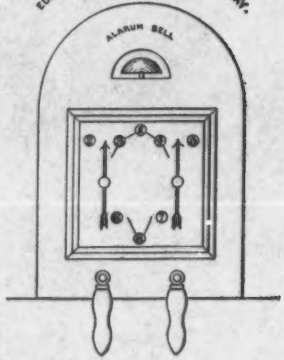
"The principles on which the electric telegraph is constructed are founded on Oersted's celebrated discovery that a magnetic or compass needle may, through the agency of a voltaic current, be invested with an artificial polarity. Thus, as a natural stream of electricity, passing round the circumference of the earth, causes magnetic needles in general to be deflected at right angles to its course, or towards the north and south poles, so an artificial stream of electricity, of adequate strength, will cause magnetic needles, placed within its influence, to be similarly deflected at right angles to its course, whatever that may be. If, then, a magnetic needle were placed parallel and near to any part of a conducting wire, which we will suppose to be laid down between London and Blackwall, the transmission of an electric current from a voltaic battery will cause the needle to change its position so as to stand during the continuance of the current at right angles to the wire, being turned in one direction or the other, according to the course of the current. If this deflection of the needle were limited by two fixed stops placed respectively at the two sides of one of its poles the motion of that pole to one stop might evidently constitute one signal and its motions to the other stop, another signal."

"The annexed engraving (Plate LX) represents some of the Blackwell Railway instruments, constructed upon the principles above explained. The signals are given by pointers, each suspended vertically on an axis, moving freely through the face of a dial. Behind the dial a magnet is fixed on the same axis as the pointer, so that both move together. A portion of the conducting wire is coiled many times longitudinally round a frame, in which the magnet moves, so as to subject the magnet to the multiplied deflecting force of the voltaic current. The motion of the magnet is limited at both sides by fixed stops. Now, suppose three of these very simple instruments, included in the same conducting wire, to be placed one at the Minories, a second at Blackwall, and the other at some third point. The general effect of this arrangement would be that the transmission of electricity along the conducting wire, and therefore through the convolutions of wire surrounding the respective magnets, would deflect those magnets with a sudden and decided motion to one of the stops, and cause the exterior pointers to indicate corresponding and simultaneous signals upon the dials of the three instruments. Each instrument is provided with a battery, and a handle, by which a porter or policeman is enabled at pleasure to connect the conducting wire with his battery. By



EDINBURGH AND GLASGOW RAILWAY.
8 SIGNAL TELEGRAPH





TELEGRAPH ON THE GREAT WESTERN RAILWAY.

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TRANS. AM.
VOL. X
O'DONNELL ON

PLATE LX.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXXII, No. 738.
O'DONNELL ON RAILROAD SIGNALING.

TELEGRAPH ON THE GREAT WESTERN RAILWAY.

moving the handle to the right or left, either of the signals can be instantaneously transmitted from any one of the instruments to all the others, which, by means of their own handles, have the power of sending back signals in reply, correctness being ensured by the simultaneous appearance of the signal in the instrument of the operator and that of the recipient. The transmission of intelligence is prefaced by sounding a bell by which attention is obtained, an operation effected through the agency of the voltaic current."

The engraving also represents one of the instruments upon the Edinburgh and Glasgow Railway, being a combination of two of the above elementary telegraphs. Each needle is here worked by its distinct handle. By the single movements of the pointers, the figures 2, 3, 4 and 5 may be given. If the two pointers are made to converge upwards at the same time, their combined indication will be the figure 1; or if they converge downwards, 8. If the pointers are made to rest diagonally, parallel to each other in one direction, 6; in the other, 7 is indicated. Eight distinct signals are thus obtained, which, in connection with a code, are sufficient for all ordinary purposes. By combining several elementary telegraphs, any number of signals may be obtained. A drawing of the telegraph employed on the Great Western Railway, worked by keys, and having a peculiar arrangement of the conducting wires, not necessary to be explained, is subjoined to illustrate this point.

Plate LXI illustrates the modern single needle instrument used for block working, and as generally in use in England. Fig. 1 is a front view, showing the outside appearance of the instrument. Fig. 2, a front view, with the cover and that part of the case carrying the operating handle removed; and Fig. 3, a side view.

The material difference in principle in this instrument to that introduced by Messrs. Cooke & Wheatstone is in the substitution of a soft iron armature inside the coils in place of a permanent magnet, and the addition of a comparatively large permanent magnet outside the coils to control the position of the armature when no current is passing through the coils. Beyond this, the improvement consists in the better form and construction of the instrument in its various details.

The instrument in its present form is much less liable to be affected by lightning or earth currents, and, if affected, will only be momentarily so. Should the polarity of the permanent magnet be reversed, it would not affect the working of the instrument.

Cooke & Wheatstone's block system was put into operation on the Norwich and Yarmouth Railway in 1844. It is curious that in this instrument the exact words which are now most generally adopted in England, viz., "line clear" and "line blocked," were actually employed.

Notwithstanding the efforts made, both before and after the year 1844, it is curious to note the various changes which took place in block working on railways before the present system was adopted, which is practically the same as the early forms described by Cooke & Wheatstone.

In the winter of 1843–44 an accident occurred on the Lickey incline of the Birmingham and Gloucester Railway; and as a consequence, block working was introduced and carried out by complete telegraphic messages in place of arbitrary signs, "line clear" and "line blocked."

In 1851, Mr. C. V. Walker, the telegraphic engineer of the Southeastern Railway, suggested the carrying out of block working by a code of rings on bells, and for upwards of 12 years the trains of the Southeastern Company were worked by audible electric signals. Throughout these 12 years no single needle instrument or its equivalent was used, the whole of the telegraphic signaling of the trains being carried on exclusively by sound. In 1855 the same company made a trial at Tunbridge of a form of block instrument having two miniature semaphore arms in place of the needles. This, the author believes to have been the first instance where an attempt was made to assimilate the block instrument with the outside visual signal.

From this time onward the block systems adopted on the various railways could be classed in two divisions, the great majority using the needle instrument as described by Cooke, the remainder employing the semaphore instrument as introduced by Mr. Walker.

In the comparatively early days of signaling there were three papers read before the Institution of Civil Engineers (England) on "Railway Accidents." The first by Capt. Huish, in 1852; the next by Sir James Brunlees, and the last by Sir Douglas Galton, R. E., F. R. S., the last two papers in 1861. As bearing on the time interval of block working, Sir James mentions the Welwyn accident on the Great Northern Railway. He says:

"On the Great Northern Railway in the Welwyn accident, only one train out of four which were concerned kept its time, and this one ran

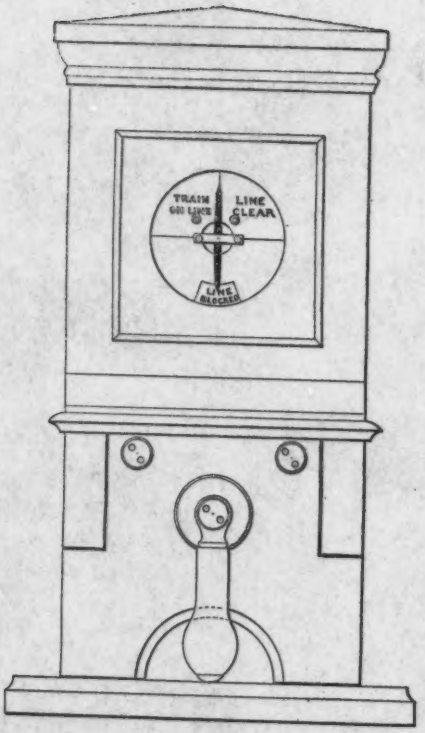

TRAIN ON LINE
LINE CLEAR
LINE BLOCKED

Fig. 1

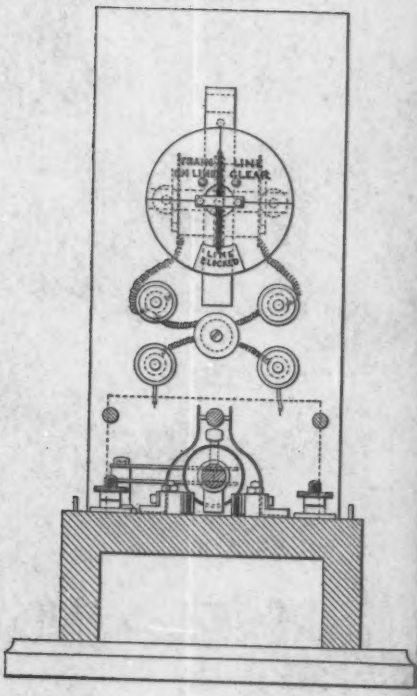

TRAIN ON LINE
LINE CLEAR
LINE BLOCKED

Fig. 2

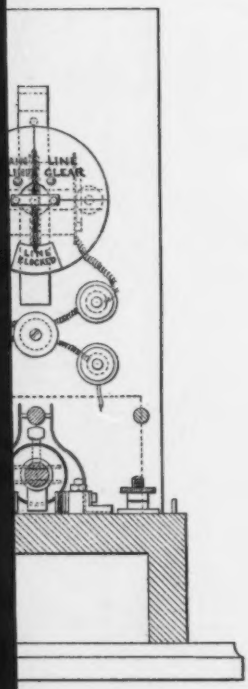


Fig. 2

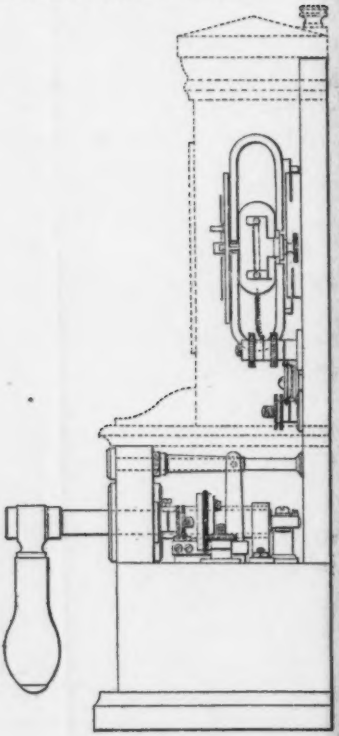


Fig. 3

into another which was an hour too late. On the same line in a collision at Hatfield, the three trains concerned were, respectively, 3 hours 10 minutes, 2 hours 47 minutes, and 1 hour 40 minutes late. In an accident on the London and Southwestern Railway, a passenger train timed to run 26 miles per hour was started two minutes after a goods train timed to run at 16 miles per hour, and, as a consequence, the passenger train ran into the goods train before it had gone 4 miles from the starting point. The number of instances in which unpunctuality and the starting of one train too soon after another have been the cause of accidents are far too many to be referred to separately. The author need, however, only allude to the Clayton tunnel accident to illustrate his remarks on this head.

"A general rule has been laid down that five minutes ought to elapse from the starting of trains from each station, but this cannot be made generally applicable, as so much depends on the class of trains succeeding each other, such as their rates of speed, or there being stopping trains or otherwise. In many instances an interval of five minutes may be enough, but in others it is manifestly insufficient, for, though trains may be started from a station at the stated intervals, they will, from various causes, be unable to preserve the same distance from each other. More attention is required to this point than to that of their starting. The system of working the traffic of a railway by allowing an interval of time between the trains is unsatisfactory and dangerous, and far inferior to that of allowing an interval of space."

An amusing incident bearing on time interval, showing how even allowing an enormous latitude is not sufficient, came under the author's notice. A train started from a terminus on Monday, and another on the following Wednesday (the exact hour is a mere detail), and Wednesday's train collided with Monday's. Sir Douglas Galton, R. E., F. R. S., in his paper, says that about that time (1862) between £100 000 and £120 000 was annually paid as compensation for railway accidents.

From the published returns for the year 1854 upon accidents in Great Britain, it appears there were 85 accidents specially reported upon, resulting in the following, viz.:

Killed	233
Injured	453

of which numbers 283 suffered in collisions between trains. Of these 85 accidents there were no less than 52 which arose from collisions, or nearly 61.18% of the accidents from all causes.

Compare this with the Board of Trade returns for 1893.

SUMMARY OF ACCIDENTS AND CASUALTIES WHICH HAVE BEEN REPORTED TO THE BOARD OF TRADE AS HAVING OCCURRED UPON THE RAILWAYS IN THE UNITED KINGDOM DURING THE YEAR ENDING DECEMBER 31ST, 1893.

1. *Accidents to Trains, Rolling Stock, Permanent Way, etc.*—Accidents to trains, rolling stock, permanent way, etc., caused the death of 27 persons and injury to 557 persons, viz.:

	Killed.	Injured.	TOTAL FOR THE YEAR 1892.	
			Killed.	Injured.
Passengers	17	484	21	601
Servants of companies	10	73	9	92
Total	27	557	30	693

During the year there were reported 27 collisions between passenger trains or parts of passenger trains, by which 86 passengers and five servants were injured. Forty-five collisions between passenger trains and goods or mineral trains, etc., by which 157 passengers and 11 servants were injured. Twenty collisions between goods trains or parts of goods trains, by which one servant was killed and 17 were injured; two cases of trains coming in contact with projections from other trains traveling on parallel lines, by which one servant was killed and three passengers were injured; 54 cases of passenger trains or parts of passenger trains leaving the rails, by which 15 passengers and five servants were killed, and 82 passengers and 11 servants were injured. Eleven cases of goods trains or parts of goods trains leaving the rails, by which one servant was killed and two were injured; seven cases of trains or engines traveling in the wrong direction through points, by which one servant was killed and five passengers and one servant were injured; 23 cases of trains running into stations at too high a speed, by which 121 passengers and five servants were injured; 162 cases of trains running over cattle, or other obstructions on the line, by which one person was killed and 16 passengers and other persons were injured; 40 cases of trains running through gates, at level crossings, by which one passenger was killed and one servant and two other persons were injured; four cases of the bursting of tubes of engines, by which one servant was injured; 10 cases of the failure of machinery, springs,

etc., of engines, by which four servants were injured; 468 cases of failures of tires, by which one servant was injured; 18 failures of couplings, by which one passenger and seven servants were injured; one case of the failure of ropes used in working inclines, by which one servant was injured; four cases of slips in cuttings or embankments, by which one servant was killed and five passengers were injured; and four other accidents by which four passengers and five servants were injured.

Taking the enormous increase of traffic of to-day, as against the year 1854, and the correspondingly large decrease of accidents, is it not fair to place a great deal of the credit of this most satisfactory result to the employment of reliable signaling? Some railway managers think that the latest developments of signaling tend to hamper their traffic, while others, that the cost is so great they cannot afford it; but let them take their annual accident bill and capitalize it and see how large an amount of signaling they can obtain for it in these days of keen competition; to say nothing of avoiding the discredit of accidents, while being, as they undoubted would be, pioneers in safe railway traveling, and if they are philanthropic, why they are public benefactors (not to the contractors, but to the traveling public).

The author gladly avails himself of this opportunity to pay his tribute of respect to the forethought and impartial conduct of the inspecting officers of the British Board of Trade. To that department the British public owes the immunity from accidents which has characterized the management of British railways during many years passed. The first rules issued by the department, so far as the author is aware, were issued by the Lords of the Committee of the Privy Council on April 29th, 1858. The much-discussed question of interlocking and the supposed credit due to its inventor is somewhat discounted by these rules. Even safety switches were enforced. Year by year additions have been made, culminating in the Regulation of Railways Act, passed by both houses of the British Parliament in 1889.

It might interest this Society to give the leading features in regard to signaling in the latest rules issued, August, 1892, by the British Board of Trade. They are as follows:

B.—Requirements.

First.—The requisite apparatus for providing by means of the block telegraph system an adequate interval of space between following

trains, and, in the case of junctions, between converging or crossing trains. In the case of single lines worked by one engine under steam (or two or more coupled together) carrying a staff, no such apparatus will be required.

Second.—Home signals and distance signals for each direction to be fixed at stations and junctions, with extra signals for such dock or bay lines as are used either for the arrival or departure of trains, and starting signals for each direction at all passenger stations which are also block posts. On passenger lines all cross-over roads and all connections for goods, mineral lines and sidings to be protected by home and distance signals, and, as a rule, at all important running junctions a separate distance signal to be provided in connection with each home signal.

Signals may be dispensed with on single lines under the following conditions:

(*a*) At all stations and siding connections upon a line worked by one engine only (or two engines coupled together), carrying a staff, and when all points are locked by such staff.

(*b*) At any intermediate siding connection upon a line worked under the train staff or ticket system, or under the electric staff or tablet system, where the points are locked by the staff or tablet.

(*c*) At intermediate stations which are not staff or tablet stations upon a line worked under the electric staff or tablet system, sidings, if any, being locked as in *b*.

Third.—The signals at junctions to be on separate posts or on brackets; and the signals at stations, where there is more than one arm on one side of a post, to be made to apply—the first or upper arm to the line on the left, the second arm to the line next in order to the left, and so on; but in cases where the main or more important line is not the one on the left, separate signal posts to be provided, or the arms to be on brackets. Distance signals to be distinguished by notches cut out of the ends of the arms, and to be controlled by home or starting signals for the same direction, when on the same post. A distance signal arm must not be placed above a home or starting signal arm on the same post for trains going in the same direction.

In the case of sidings, a low short arm and a small signal light, distinguishable from the arms or lights for the passenger lines may be employed, but in such cases disk signals are, as a rule, preferable.

Every signal arm to be so weighted as to fly to and remain at danger on the breaking at any point of the connection between the arms and the lever working it.

Fourth.—On new lines worked independently, the front signal lights to be green for "all right," and red for "danger"; the back lights

(visible only when the signals are at danger) to be white. This requirement not to be obligatory in the case of new lines run over by trains of other companies using a different system of lights.

Fifth.—Facing points to be avoided as far as possible, but when they cannot be dispensed with, they must be placed as near as practicable to the levers by which they are worked or bolted. The limit of distance from levers working points to be 180 yds. in the case of facing points, and 300 yds. in the case of trailing points on the main line, or safety points at sidings.

In order to insure that the points are in their proper position before the signals are lowered, and to prevent the signalman from shifting them while a train is passing over them, all facing points must be fitted with facing point locks and locking bars, and with means for detecting any failure in the connections between the signal cabin and points. Length of the locking bars to exceed the greatest wheel base between any two pairs of wheels of the vehicles in use on the line, and the stock rails to be tied to gauge with iron or steel ties. All points, whether facing or trailing, to be worked or bolted by rods and not by wires, and to be fitted with double connecting rods.

Sixth.—The levers by which points and signals are worked to be interlocked, and, as a rule, brought close together, into the position most convenient for the person working them, in a signal cabin, or on a properly constructed stage. The signal cabin to be commodious and to be supplied with a clock and with a separate block instrument for signaling trains on each line of rails. The point levers and signal levers to be so placed in the cabin that the signalman when working them shall have the best possible view of the railway, and the cabin itself to be so situated as to enable the signalman to see the arms and the lights of the signals, and the working of the points. The back lights of the signal lamps to be made as small as possible, having regard to efficiency, and when the front lights are visible to the signalman in his cabin, no back lights to be provided. The fixed lights in the signal cabin to be screened off, so as not to be mistakable for the signals exhibited to control the running of trains. If, from any unavoidable cause, the arm and light of any signal cannot be seen by the signalman, they must, as a rule, be repeated in the cabin.

Seventh.—The interlocking to be so arranged that the signalman shall be unable to lower a signal for the approach of a train until after he has set the points in the proper position for it to pass; that it shall not be possible for him to exhibit at the same moment any two signals that can lead to a collision between two trains; and that, after having lowered the signals to allow a train to pass, he shall not be able to move any points connected with, or leading to, the line on which the train is moving. Points, also, if possible, to be so interlocked as to avoid the risk of a collision.

Home or starting signals, next in advance of trailing points, when lowered, to lock such points in either position, unless such locking will unduly interfere with the traffic.

A distant signal must not be capable of being lowered unless the home starting signals in advance of it have been lowered.

Eighth.—Sidings to be so arranged that shunting operations upon them shall cause the least possible obstruction to the passenger lines. Safety points to be provided upon goods and mineral lines and sidings at their junctions with passenger lines, with the points closed against the passenger lines and interlocked with the signals.

Ninth.—When a junction is situated near to a passenger station, the platforms to be so arranged as to prevent, as far as possible, any necessity for standing trains on the junction.

Tenth.—The junctions of all single lines to be as a rule formed as double-line junctions.

For interesting information regarding the early forms, uses and experiments relating to block working on railways, the author has availed himself of the paper read by Mr. W. H. Preece, C. E., before the Institution of Civil Engineers, on June 13th, 1863. A perusal of both the papers and the discussion, and many of the decided opinions expressed therein, would startle some of the railroad men of the present day.

In the early stages one instrument was used for both up and down lines, and it was not to be wondered at that this system was the cause of accidents, notably the Clay Tunnel accident, when the telegraph, after working there satisfactorily for 10 years, failed at last.

To the London and Northwestern Railway is due the credit of two important advances in block working. Mr. Edwin Clarke, M. I. C. E., of that railway, was the first to introduce separate instruments for each set of rails, and, about the year 1853, a third position was added to the block instruments, which third position consisted of the needle being in the central (vertical) position intimating "line blocked." Constant currents were maintained on the wires of these instruments by pegging the needles over, as they do now, to one side or the other, and the wires were brought down to within reach at every alternate post, giving guards and other persons a means of communicating the occurrence of an accident by severing the wires which caused the needle to assume the vertical position. Bells on independent wires were used with this system of Mr. Edwin Clarke.

It is worthy of notice that the London and North Western Company only applied this system for permissive block working.

Mr. Preece truly says, that "this adulterated form of the block system is not sufficient under all circumstances to prevent collisions," and he instances the case which occurred near Wolverton on the 22d of February, 1862. Further he says:

"There are evidently great and serious objections to the working of railways upon the space or block system in preference to the time system," and states that "the London and North Western, the Great Northern and other railway companies have been compelled to abandon it. The telegraph becomes simply the medium of warning or caution, excepting in the case of long tunnels and steep inclines; it enables all slow trains or trains behind their time to hasten on because they are made acquainted of clear lengths before them; while all fast trains or trains before their time are informed that there is a train in front of them and are delayed without being actually stopped."

The London and North Western Company thought that the line could not be worked if a distance of 2 miles on an average was maintained between the trains, and it was of course obvious, as Mr. Preece remarked, that if 2 miles was a serious objection and an impossibility, why not shorten the distance?

In the light of later experience, railway managers had to, and did admit, that they could not work the heavy traffic passing over railways without the assistance and certainty afforded by the block system. This is specially so where trains follow each other at such short intervals as sometimes one, two, or three minutes.

It is believed to be a fact that even in the early days the Great Northern Railway of England, which is certainly a pioneer line and one that has all the latest improvements, used the two-needle instruments, and the needles were promiscuously used for the up or the down line as the occasion offered. The left-hand needle was used for passenger trains, and the right-hand one for engines, goods, cattle and ballast trains, and the signalman had to hold the handles to retain the needles in position.

Mr. Preece puts in instruments on his system (which was substituting the semaphore arm for the needle in the block instrument and thereby loosing the third position of the needle instrument) between Queen Street and St. David's Stations, Exeter, in March, 1862.

Briefly, Mr. Preece sums up the advantages of the application of

the telegraph to the working of single lines by stating "when the telegraph is used, safety is assured, regularity obtained, and single lines become as secure and rapid as double lines."

The author wishes it to be understood that in the retrospective part of this paper, in relation to the early defects of block working and the views expressed in the various papers, he is not offering any remarks of his own. The various documents containing these opinions are at the convenience of the public, and any historical retrospect of block working would be incomplete if the various changes of opinion in relation to the various systems were not incorporated.

The one remarkable feature is that the very first attempts at block working struck the right line, and, so far as the block working in England is concerned, substantially, it is the block working of to-day.

It was even stated in the discussion at the Institution of Civil Engineers in 1863, that one wire was an element of safety as well as economy, and further, with three wires, if a fracture of one of them took place, the fractured wire might foul one or both of the remaining wires, and that with a persistent current flowing, falsified signals might be sent. In the present system of working such an accident could not happen.

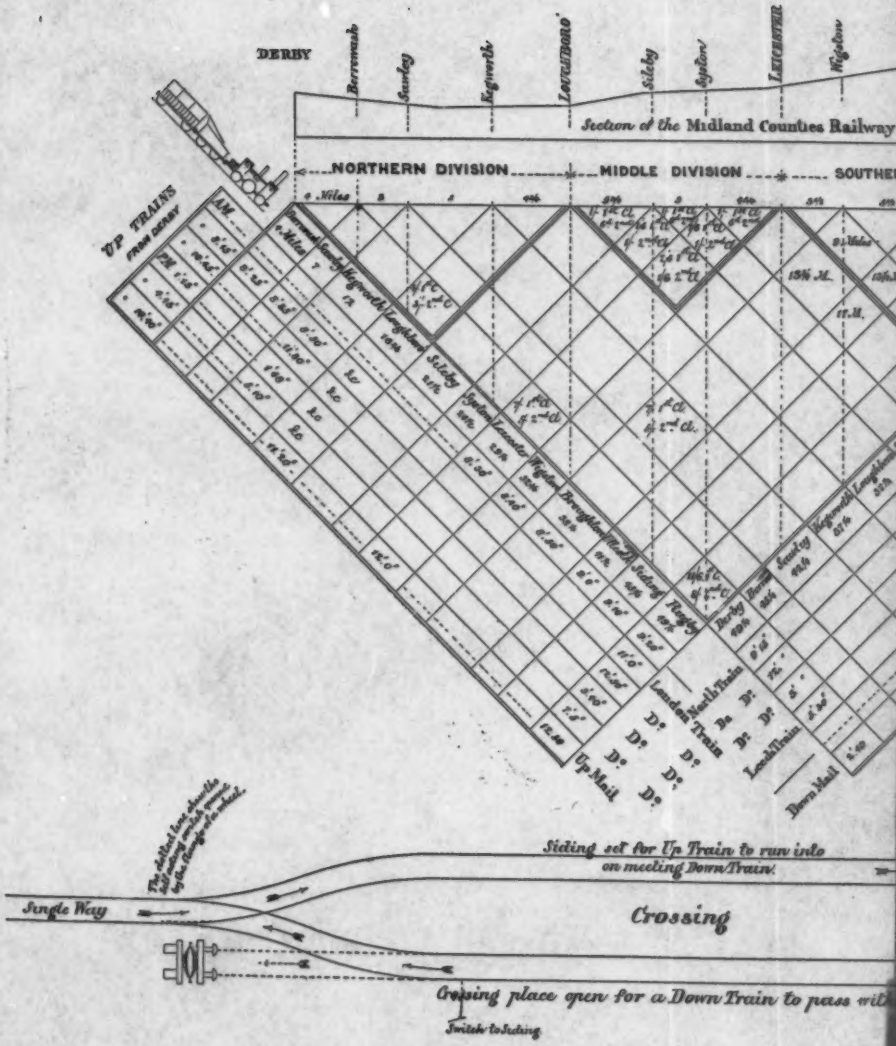
To Mr. C. V. Walker is due the credit of introducing the system that every signal made by one man should be correctly repeated by the man that received it as an intimation of the understanding of the signal.

Mr. Walker was also the first to use balanced currents for the working of bells. This knowledge was communicated to the Royal Society in 1857. It is a curious instance to find that a patent had been obtained for this purpose by another Mr. Walker, of Glasgow, anticipating in principle the invention of Mr. C. V. Walker, of the Southeastern Railway.

As early as 1856, Mr. Walker forwarded a paper on train signaling to the Institution of Civil Engineers, but, the subject not being then found attractive, it was not read.

In view of the fact that a large proportion of the automatic signaling which has been installed in this country has for its normal position the line at "safety," or the semaphore arm in the "safety" attitude, it may be mentioned that in the early days of railways, the line itself was considered as clear, but when sanction was given to the rear, that sanction intimated that the line was blocked. This, no doubt,

TIME, FARE AND DISTANCE



FARE AND DISTANCE TABLE

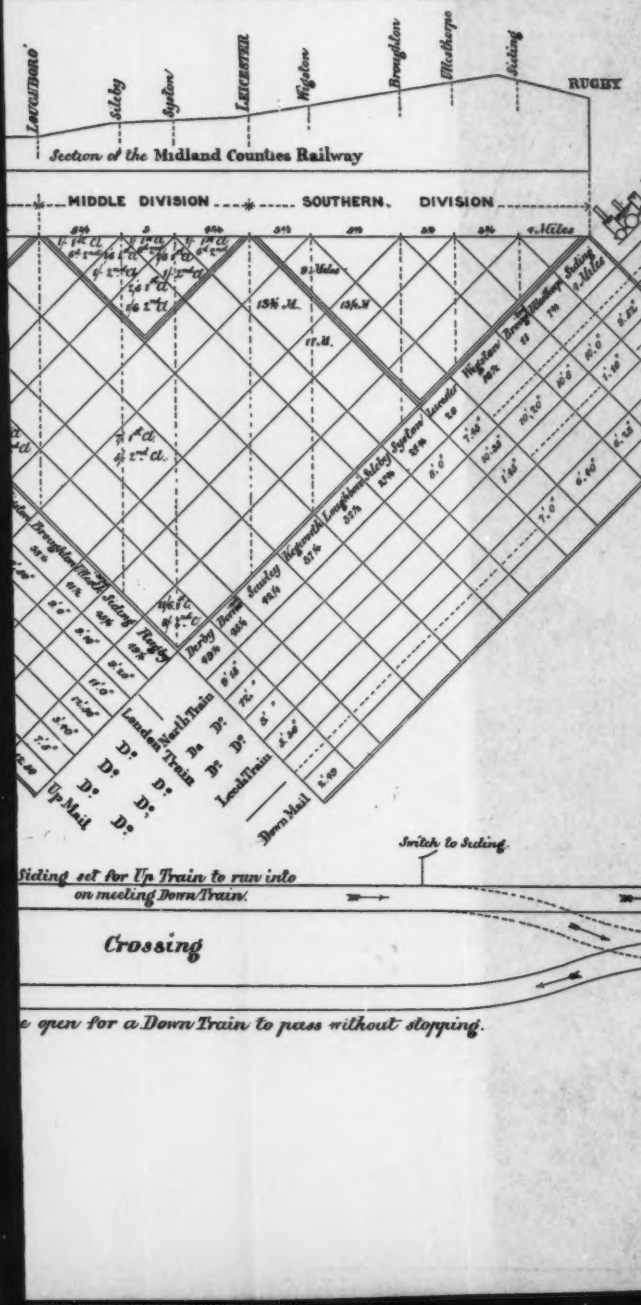


PLATE LXII.
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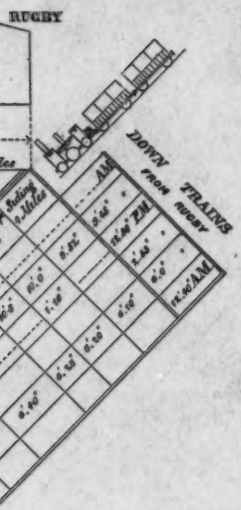
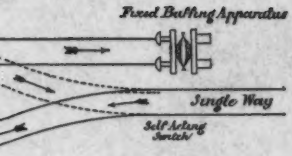
VOL. XXXII, No. 738.
L. ON RAILROAD SIGNALING.





arose from the fact that there were only two positions to the instruments then in vogue, viz., "line clear" and "line blocked."

Sir William Cooke mentions this in his pamphlet previously referred to (1842). He says:

"I think it, however, highly desirable that the ordinary or quiescent condition of the station signal should be a state of danger, not a state of safety, so that a train should never run into a station without special guarantee that it was prepared to receive it. With such an arrangement no bad consequence could arise from want of presence of mind on the part of the signalman, at a moment of sudden danger."

There may be some members of this Society who will recall the fact that Mr. Ashbel Welch many years ago laid down the fundamental rule that the normal position for the outside arm should be danger.

It is a curious coincidence that in so many cases invention repeats itself, and that the old saying "there is nothing new under the sun" is very frequently verified. Rumors have reached us in Great Britain that certain claims have been put forward by parties in the United States for the monopoly on a patent for an alleged invention of safety switches, the object and use of which is perfectly understood. It may not be considered as exactly related to "lock and block" working, but as the writer has referred to the pamphlet of Sir William Cooke frequently in this paper, he may mention that in that pamphlet there is an interesting diagram of a time, fare and distance table (Plate LXII), the lower portion of which clearly indicates the use of safety switches for preventing accidents by trains overshooting the fouling point. It might, possibly, be better to quote his exact words with reference to this matter, and it should be borne in mind that this pamphlet itself was issued in the year 1842. He says:

"The arrangement of the rails and switches at a crossing is a matter of engineering detail. I have given a sketch which will sufficiently explain to the general reader the principle on which two trains might cross without the possibility of a collision, the self-acting switches infallibly directing them to the proper side. In case of a train accidentally proceeding further than necessary, its momentum would be checked by a fixed buffer apparatus, or a steep incline in the usual way."

The author would also point out that in the diagram referred to above the lines in question are passenger roads; therefore it is practically a derail on the passenger road.

The London and North Western Railway was the first, as previously mentioned, to introduce the third position in the needle instrument, and has to the present day maintained it, and, through its example, has influenced the large majority of railways in England to adopt the needle instrument with three positions. With this system when the needle is in the vertical position, the line is considered, according to the regulation words, as "not clear," and it is understood that, previous to sending a train, sanction must be obtained on the block instrument from the cabin in advance, the signal being repeated in acknowledgment to further ensure the understanding of the message, and the needle pegged over. When the third position was introduced, the great advantage which was no doubt desired previously, but which was difficult to obtain, was seen, and the normal position of the line as "not clear" or line "blocked" was hereafter established in all systems.

Even with the "lock and block" system the author believes that, notwithstanding the strong opposition to the normal "danger" position in automatic systems of signaling, as used in the United States at the present time, the contracting companies are making a specialty of offering such systems of automatic signaling that have a normal "danger" position for the semaphore arm. This is really following out the practice generally adopted 40 years ago in England.

In automatic signaling systems it should be borne in mind that while outside visual signals are the main feature, yet incidentally it becomes an actual block system in substitution of the block instrument in the cabin where the manual system is in operation; therefore, it should incorporate the advantages and result obtained from the manual and block instruments.

It is a curious fact that the objections which the author raises today against what is known as the "Sykes'" system of "lock and block," were substantially raised against the system of Preece, which had the miniature semaphore, in 1856, and the contradictory nature of the signals was plainly set forth then. In Mr. Walker's paper of 1856, four telegrams were enumerated which illustrated the method of question and answer which Mr. Walker then considered necessary; the first was: from A to B, "May I send a train?" given by A striking one blow to B; B's answer, "Yes, you may," one blow struck back by B. A then sends on the train, and, on its arrival, B sends to

A the message: "The train you sent is in safe," by striking three blows to A, intimating this, and A replies, "All right; I understand train is in," by striking three blows to B. These blows are struck on bells.

In 1863, Mr. Walker's chief reason in objecting to miniature semaphores in the block instruments was "because the second of the above-named four signals was always contradictory, and did not mean what was intended to be conveyed." The first question, "May I send a train," was answered with the words on the bell and index, "Yes, you may not"; that was, while the bell replied "Yes," the semaphore went up or the index went over, which meant "No." It was true that "No" was understood to refer to any train that might follow the one in question, although it did not say so; but some day the index might say "No" and mean "No."

This is curiously enough the case with certain lock and block systems of to-day, and the author will refer to them later in comparing the various lock and block systems.

In 1863 it was practically agreed, in the discussion at the Institution of Civil Engineers, that a block system should be made legally obligatory on railway companies, but, as an illustration of the slow march of governments, it was not until the Regulations of Railways Act, 1889, that it was made so. The author might even remark that he believes that it is not obligatory in the United States. One gentleman remarked in 1863 in the discussion at the Institution of Civil Engineers, that

"No doubt the block system for crowded traffic might answer very well, but so long as the traffic could be carried on without the necessity for its aid, there was, in his opinion, a positive advantage in ignoring it and depending on the ordinary mode of signaling."

Having briefly traced the early stages and development of block working, the author will now trace the introduction of fixed signals and development of interlocking between levers operating points and signals.

Fixed signals, without which, of course, no system of block working can exist, were first brought into general use with the opening of the Grand Junction Railway in 1838, and at about the same time on the Liverpool and Manchester Railway. The signals were in the form of a semi-circular or D-shaped board, elevated on a pole and revolving

through an arc of 90°. The disk towards the driver indicated "danger," and the edge "clear." A light for a night signal was used in connection with these disks. Several forms of signals have been suggested and tried since the above were brought into use, but at the present time the recognized forms of signals are the semaphore, for running lines (introduced by Mr., now Sir, Charles Hutton Gregory, K. C. M. G., Past President Institution Civil Engineers, on the Croydon Railway in the early part of the year 1842), and low-revolving disk signals for crossing, sidings, etc. The semaphore signal was an adaptation of the old form of semaphore used for telegraphing to short distances, and has proved to be, perhaps, the most important step in the development of railway signals.

With the adoption of fixed signals it soon became evident that, to avoid the giving of a signal contrary to the position of the switches of the main and siding crossings, some form of interlocking between the two must be devised.

We read of Mr. Atkinson, at East Retford, in 1852, providing a lock between a signal and a pair of switches, and in the following year Mr. Whitworth proposed a notched bar connected to the signal wire and crossing at right angles another notched bar working in connection with the switches.

As the number of switches and signals to be worked increased, it became advisable and necessary to concentrate the levers working the same together in one place, and the principle of interlocking a signal and a pair of switches being known, it would appear simple to interlock the levers concentrated together; but it was not until 1859 that complete lever-locking apparatuses were applied by Mr. Austin Chambers for Kentish Town and Willesden Junction. Mr. Farmer, however, claims that Mr. Saxby, in 1856, fixed at the Bricklayers' Arms Junction of the Brighton Railway a lever frame of 14 levers properly interlocked so that no signal could be given inconsistent with the position of the points, and that the arrangement was patented in that year (1856). No patent was taken out by Mr. Austin Chambers until 1860, and probably Saxby's patent of 1860, after Mr. Chambers', is the first of Saxby's which can be said to cover a complete interlocking lever frame. In 1867 the concentration of point and signal levers and the proper interlocking of the same really began with the introduction of Saxby and Farmer's spindle locking, Messrs. Stevens & Sons' tappet locking, and

Messrs. McKenzie, Clunes & Holland's system of interlocking. The next step was the catch actuating of the interlocking, designed by Messrs. Easterbrook and Saxby in the same year (1867).

From this time various forms of interlocking, both catch actuated and worked direct from the lever, and adaptations of interlocking for special purposes, have been devised, but the principle remains the same.

For some time the arrangement of fixed signals, with levers to work them, and the switches concentrated and interlocked and block telegraph working independent of each other, was thought to be quite safe and sufficient, but accidents have occurred which show that, owing to the forgetfulness of the signalmen, something more is desirable, *i. e.*, a combination of "lock and block," in such a manner that it is impossible for the outside signals to be lowered, excepting when the line is "clear" and the proper telegraphic signals have been given and accepted.

Automatic signaling is an attempt to obtain "lock and block," or "trains commanding the section," and eliminating human agency. It may be argued that all forms of automatic signaling meet the objections against fixed signals and block telegraph worked independently. With regard to purely mechanical automatic signaling, it is limited by distance, and may, for this reason alone, be dismissed as unsuitable.

Several systems of automatic signaling, operated mechanically, have, however, been tried.

In the year 1858 the North London Railway Company tried between Hackney and Kingsland Baronowski's self-acting block system. In this system when a train passed over a lever arrangement the signal was put to "danger," and remained in that position until the train had reached a point 1 100 yds. ahead, when the movement of another lever, by the train passing over it, caused the signal in the rear to go to the "clear" or "off" position. This system failed and caused a serious collision, and was consequently discarded.

Another early form of automatic block working was introduced by Mr. Whitworth and patented by him in 1853, but a signal failing at Radcliff Bridge in 1859, and another at Clayton Tunnel in 1861, it was abandoned. The Clayton Tunnel failure caused the death of 23 passengers, and injuries to 176. It was considered that after this such signaling might be dispensed with.

So far as signaling in England is concerned, automatic signaling was never put into practical operation from the early experiments of Baronowski and Whitworth until the experiment on the Freshwater Railway, Isle of Wight. In this case the Board of Trade Inspectors ordered its removal.

The next and only instance of automatic signaling in England is that fixed on the Liverpool Overhead Railway on the Timmis system.

The Timmis System.—In this system there is at each station a home signal and a starting signal, the latter also acting as the distant signal for the station in advance, the block sections being short. These signals are worked electrically, and the conditions laid down by the English Board of Trade with regard to automatically working them were:

First.—That each signal must be put to the "danger" position by the train as it passes the signal.

Second.—That every train must always have behind it one signal, at least, in the "danger" position.

Third.—That when a train passes a signal, and automatically puts such signal to "danger," the passage of the rear vehicle of the train past such signal must be the only means of completing the electric circuit necessary to automatically lower the signal in the rear.

(In practice the passing of the rear vehicle of a train is made to put the signal immediately past to "danger" by breaking contact, and to lower the signal in the rear by making contact.)

The main feature of this system is the Timmis patent long-pull electro-magnet, those in use on the Liverpool Overhead Railway having, with a current of 5 ampères and 50 volts, a pull of 70 lbs. at 1½ ins. distance. These magnets are used to lower ordinary semaphore signals, but when the magnet has done its work and the armature is practically in contact with the core of the electro-magnet, the current is reduced to $\frac{1}{10}$, *i. e.*, 5 ampères, by automatically switching resistance into the circuit.

Supposing a train to be at Station A, between the home and starting signals at that place, the home signal will be in the "danger" position, and, assuming there is no train in the section ahead, the starting signal in the "safety" position. The train now leaves Station A for Station B. On passing A's starting signal, that signal will be put to "danger" and A's home signal lowered to "safety," which will

allow another train to enter Station A. A's starting signal being at "danger," this second train will have to wait at A until the first train has passed the home signal at B, the passing of this signal by the rear vehicle of the first train being necessary to complete the circuit through the coils of the special long-pull magnet operating the starting signal at A.

We now turn to the automatic system, which appear on the increase in the United States.

The Hall System.—In considering this system, the main feature of distinction between it and other systems lies in the fact that a substitute is used for the semaphore arm.

The consensus of opinion in all parts of the world on railroads which pretend to be modern approves the semaphore arm. It therefore becomes the duty of the promoters of a departure to give their reasons for the departure rather than argue the question.

The Pneumatic Automatic.—The question of expense is not one which comes within the province of this paper. This system seems to find favor with some of the railroads, but there would appear to be an unnecessary number of agencies employed to give the desired result. By agencies is meant different powers, such as steam or its equivalent, electrical, pneumatic. This much can be said in its favor, it incorporates the ordinary semaphore arm as its outward indication to enginemen. It is in itself a block system.

Although various other systems of automatic signaling have been tried, some of which are now in experimental operation in the United States, the author does not propose to treat upon them in detail, because automatic signaling cannot be the signaling of the future, in either the United States or any other country, from the simple fact that as soon as a switch is interposed, automatic signaling becomes at variance with the power or means of operating the switch. It is, of course, to be expected that the various stations and junctions will develop to the extent that switches and crossings must be operated from a central position in order that some system of interlocking control can be arranged between the several signals referring to the passenger lines and the conflicting switches; and as the switches cannot be operated by the automatic system, there must be two systems, if the automatic is to remain.

It would appear to be the cheapest and best system for the trunk

lines, at all events, to have their system of signaling of such a nature that one power may be subsequently employed for operating the switches and the other parts, when occasion demands it.

In considering the various systems which have been before the public, and which can fairly claim to be "lock and block" systems, we may mention, first, the Sykes system, which is the invention of Mr. William Robert Sykes, Sr., the Spagnoletti system and the Patenall system.

The system which has found the most favor, in fact which has monopolized the largest amount of installations of "lock and block," either in England or the United States, is the Sykes system.

It may here be mentioned that, taking railroads in all parts of the world, Great Britain not excepted, in the author's opinion the New York Central and Hudson River Railroad is the best signaled, and, consequently, the best protected, line in the world. This may appear a broad statement to make, but when it is considered that the New York Central and Hudson River railroad has, firstly, the interlocking system, and superadded to that, secondly, the union of the lock and block system (Sykes) over the majority of their lines, it completely bears out this statement. No line in Great Britain has so many lines of railroad protected by the lock and block system.

The author considers that great credit is due the management of that road for thus early appreciating the responsibility of a great corporation, and, doubtless, the American traveling public also fully appreciates the willingness of the company to safeguard their patrons.

A description of this system will serve to some extent to describe the systems also, so far as the results effected, of Spagnoletti and Patenall. There are certain features which in all these three systems, and certainly in the Sykes system, appear to be at variance with the condition of the line.

The Sykes (as used in England) system embodies in the instrument a miniature semaphore arm and tablets with the words "locked" and "free" and "blank" and "train on"; the normal position of the miniature semaphore being in the "safety" attitude, meaning "line clear," the dials illustrating in the normal position "locked" and "blank"; the word "locked" referring to the starting or sectional signal lever, and "blank" referring to the train movement as no

Fig. 4

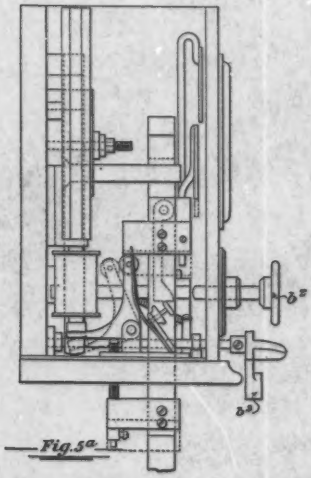
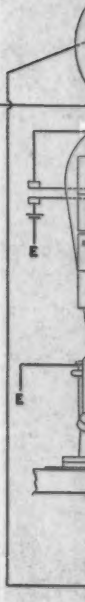
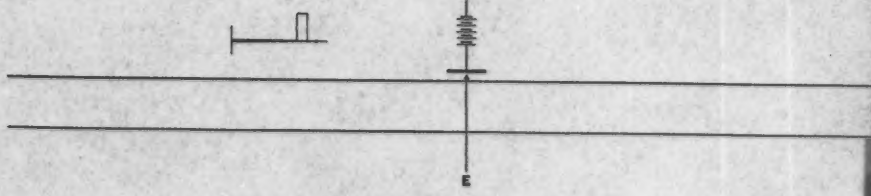


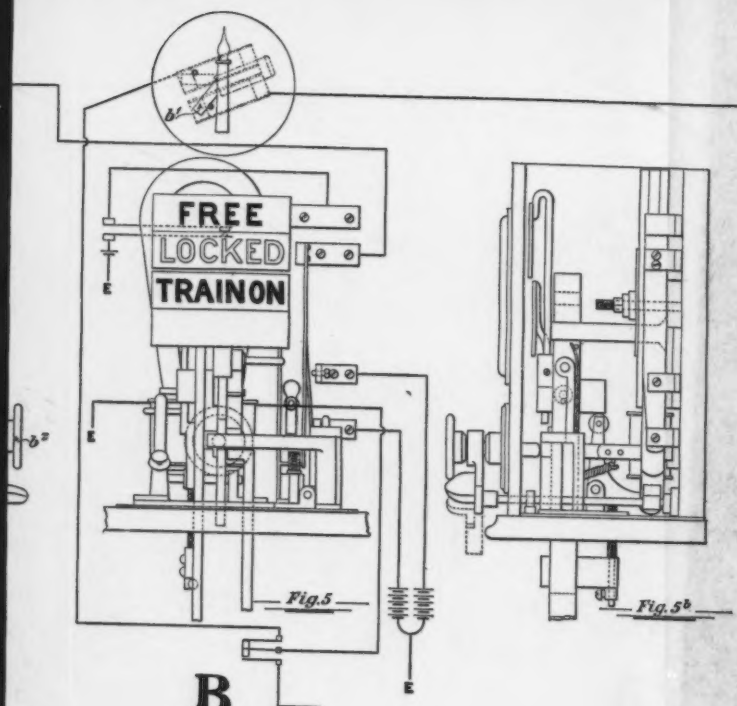
Fig. 5a



A

— THE "SYKES" LO





B

KES" LOCK & BLOCK SYSTEM.

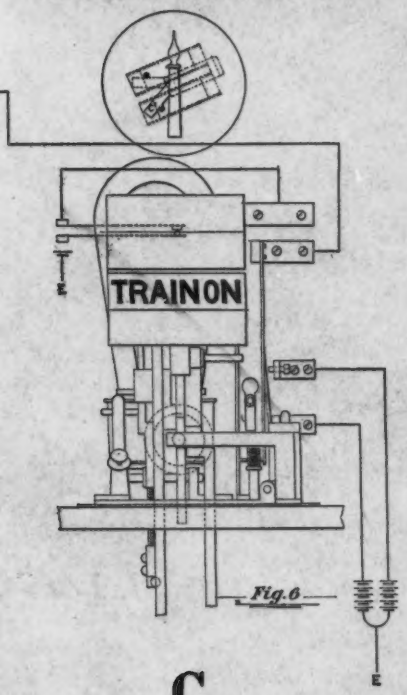


Fig. 6.

C

sanction given. Normally the miniature semaphore arm is maintained in the safety position by the current from a single cell battery.

The working under this system would be somewhat as follows: Referring to Plate LXIII, A, B, and C are three sections, and the three sections are assumed to be intermediate sections, neither A, B nor C being terminal, and, therefore, double instruments are shown at A and C, as well as at B. These instruments illustrate both receiving and sending portions.

Supposing B has given sanction to A, and the necessary instructions have been followed and the train to be traveling between A and B, B's instrument is locked and the two apertures in the instrument at B would disclose the word "locked" on the upper one, and "train on" on the lower one. Before B can lower his starting or sectional signal for the train to enter the section B-C, B by bell code will ask C to release his starting signal lever, C responds by plunging, which causes the upper dial at B to show "free," and the miniature semaphore arm b' to assume the "danger" position; it also causes the lower dial at C to show "train on." D then pulls over his starting signal lever, and this action causes the upper dial at B to change from "free" to "locked," indicating that the lever cannot be fully returned to its normal position, and also alters the circuit, so that, when the train passes over the treadle in advance of the starting signal at B, the lower dial at that place is changed from "train on" to blank, and B is then in a position to plunge again to A. The returning of the starting signal lever at B to the normal position intimates at A by the lowering of the miniature semaphore arm a' to the "safety" position that the line is again clear as between A and B.

In case B should from any cause whatever have to stop the train at his station after having received permission from C for it to enter the section B-C, and the train should eventually not enter that section, the instruments at B and C are made to resume the normal position by the use of a key which in the case of B does, electrically, what the passing of the train over the treadle in advance of B's starting signal would do, B being obliged to pull over his starting signal lever and insert the key to release the back lock from it, allowing it to be returned normal, which action puts his instrument into the normal condition of lever dial showing "locked," train dial blank and miniature semaphore arm a' at A at "safety." The use of the key at C only

mechanically releases his instrument and causes the train dial to show blank, the lever dial of course remaining normal showing "locked," assuming that no sanction had been given from D.

At this point it would be well to consider the statements that have been made with regard to this system, which would appear to lead the public to suppose that accidents are impossible with either of these systems. It is stated that "mistakes by the operators are rendered impossible, and any derangement in mechanism or misunderstanding in orders will never result in anything more serious than delay."

Take the case previously referred to, that C for any reason does not desire the train for which he has previously given sanction to A, and released B, to come into his section. In the usual course C bells back to B to cancel his signal, and himself cancels his own signal mechanically by the use of his key, thereby returning his own instrument to the normal condition in which he is free to accept another train from B and to perform any movements at his section that are desirable. B, on receiving intimation from C that C wishes the previous sanction to be canceled, acknowledges back on the bell that he has understood the signal and says that he will cancel. Meanwhile some other duty takes his attention, and he does not cancel; a train arrives at B's starting signal, and B, having already lowered his starting signal, the train enters the B-C section. An interval of time elapses during which C has finished his shunting, or other movements, and B now asks for sanction to send another train, and C gives him such sanction. The sections are short. B may suppose that the train he had previously sent (unknown) to C had arrived at C, passed out of C's section and C given sanction for another train; B therefore allows a second train to enter the B-C section.

Misunderstanding between B and C signalmen there certainly is, but no tampering has taken place with the instruments other than is common and usual by the insertion of keys for the purpose of cancellation, and yet two trains are in C's section at one time.

There is a still more serious objection to which all the lock and block systems previously mentioned are open, and that is, that if a train has arrived, say on the west-bound line, and it is shunted through a cross-over road on to the east-bound line, no proper means are provided by which the east-bound line is blocked. The previously described system of cancellation has to take place to free the west-

bound line, to allow the signalman to accept a train from the rear. The signalman can, under these conditions, receive a train on the east-bound line from the section in the rear although the line is blocked by the previously shunted train which may be standing between the home and starting signals. This is the most common form, so far as experience in Great Britain is concerned, of serious accident which has occurred, such as that at Norton Fitzwarren.

The normal condition of the line in the Sykes system is considered "safety."

So far as the majority of railways in Great Britain is concerned the normal condition of a line is considered as "not clear," and it requires sanction from the cabin in advance to place the line in the "clear" condition.

In the Sykes system the miniature semaphore is normally in the "safety" attitude, and it appears to be a curious anomaly that when sanction is given by the cabin in advance, the outward indication of that sanction consists in raising the miniature semaphore from the "safety" attitude to the "danger" attitude. The raising of this miniature semaphore from "safety" to "danger" in this instance is to indicate that the line is "clear," but taking the normal condition of two sections, and the section in advance wishes to intimate to the section in the rear that he is not free to accept a train and does not wish to be asked for sanction, he moves his switch b^3 locking the plunger b^2 at B, and by that action also raises the miniature semaphore arm a^1 at A from "safety" to "danger." We therefore have the action of this arm moving from safety to danger, indicating contradictory meanings. In one case it means that the line is "clear" and in the other case it means that the line is "blocked."

Spagnoletti's System.—The main features of difference between the Spagnoletti system and the Sykes system consist, firstly, there is no miniature arm, and consequently, secondly, no necessity for a permanent current which in the Sykes system is holding the miniature arm to the "safety" attitude; and, thirdly, there is no back lock on the starting signal lever preventing its full return.

The system of cancellation in the Spagnoletti system is the same in result, but different in means. A glass case is provided in which is enclosed a press button, and for the purposes of cancellation the glass must be broken and the button pressed; of course, once the

glass is broken the button may be pressed any number of times for the purposes of cancellation.

The same freedom is allowed so far as shunting a train from one main line to another is concerned.

Patenall's System.—It is perfectly true, as set out in the preamble to the specification of this invention, that "This system embodies some of the generic features of what is commonly known as the Sykes system." It might probably be more correctly put by stating that it embodies nearly all the generic features of the Sykes system, these features including both those that may be good and those that the author considers defective.

The main difference consists, firstly, in avoiding the anomaly of the miniature arms in the Sykes system by having no miniature arms at all, the same as the Spagnoletti system, and consequently not having any permanent current, and, secondly, the facility claimed of being able, having once received sanction from the cabin in advance, to manipulate the starting signal lever backwards and forwards any number of times.

With reference to the first difference, if the switch b^3 in the Sykes system be moved to lock the plunger it would place the miniature arm at the section in the rear to "danger" by cutting off the current, and if this were treated as the normal condition the advantages in the Patenall system of not having a constant current on, would be obtained. Under these conditions (Sykes system) A would ask for sanction to B, B would remove the switch b^3 from his plunger b^2 which would electrically replace the miniature arm a' at A to the "safety" attitude.

With regard to the second difference between the two systems, so far as the author can understand the object in being able, in the Patenall system, to replace the lever completely to its normal position, is simply to release the interlocking of any switches in the rear and not to require a second sanction from the cabin in advance to pull the starting signal off when the train in the rear section is required to proceed. It may be observed that, if the Sykes system is carefully considered, the full advantage of being able to put the starting signal arm to "danger" in the face of the driver, to prevent him going into the next section, is allowed, as the starting signal lever can be returned almost to its normal position to allow the signal to go fully to

"danger," and, although in the Sykes system the interlocking may be retained on the conflicting switches in the rear, yet if the interlocking notches on the starting signal lever were made wider, the full privilege of taking the interlocking off the conflicting switches would be allowed without departing from the Sykes system by making any alteration which would be unauthorized.

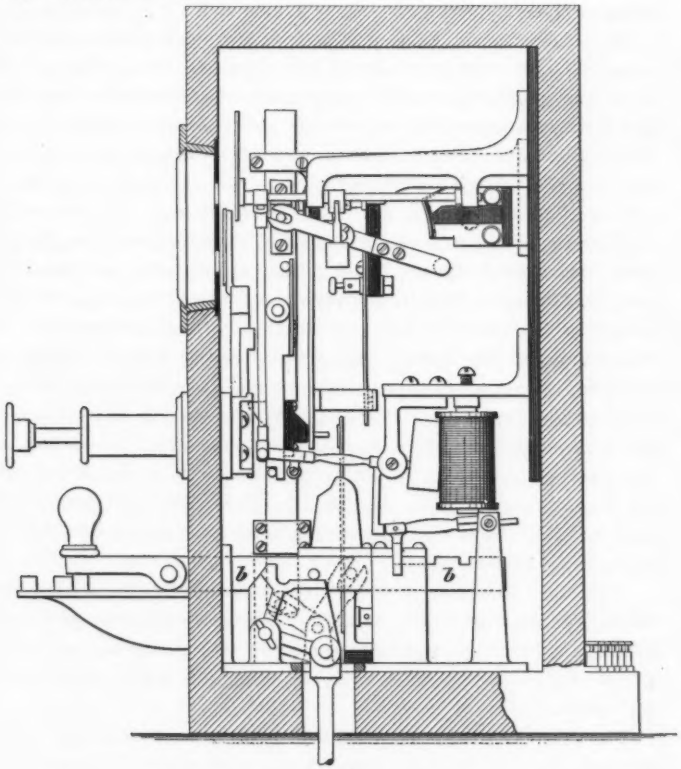


FIG. 1.

The material difference in the manipulation of the two systems (Sykes and Patenall) lies in the fact that in the Patenall system the signalman in the rear has more to do than in the Sykes system; he has an initial movement partly withdrawing the slide *b* (Fig. 1). This action brings the releasing coils into circuit with the plunger of

the section in advance, the slide b' is released so that it can be fully withdrawn, this action mechanically releases the starting signal lever, and that signal so released is free to be operated backwards and forwards any number of times; but the signalman at this post cannot give sanction for another train to approach him from his rear until the previously accepted train has passed over the treadle in advance of his starting signal.

In considering this subject, there are a few points which the author considers essential in any lock and block system. Firstly, the present facility of cancellation should be abolished. When once block sanction has been given to the rear section, the only legitimate release should be the fulfillment of the sanction. Secondly, when a train, or even any pair of wheels, is occupying a section, the obstruction should be got rid of before sanction can be given to the rear. The action of clearing the line of whatever is fouling it should release the plunger or its equivalent in its own section, thereby allowing sanction to be given to the rear. Thus, if any vehicle is moved from one main line to another, the road it leaves is automatically freed, and the road it enters automatically locked. Those who have not had the benefit of living in this country in personal contact with the railroads have therefore had little experience of the operation of electric track circuits; yet, without entering into a discussion as to the merits or demerits of the track *versus* the wire circuit system, it may be assumed that the track system should be included in this paper, from the simple fact that it seems to meet with considerable favor from certain of the railroads in the United States.

There are many features which a perfect track circuit system would obtain over the wire system, chiefly in reference to shunting operations from one main line to another, from main lines to sidings and *vice versa*, and the breaking away of coaches, and generally any obstruction on the metals.

The third essential is that a train on entering a section should automatically place the sectional signal in the rear section to "danger" independent of the operator, and it should so remain at "danger" until the train has entered the section in advance. Thus take three sections, A, B, C, a train entering the A-B section should put the "danger" A's starting or advance starting or home signal, according to the installation, and it should remain locked at "danger" until the train

has entered the B C section. Through the courtesy of a member of the joint committee on interlocking and block signals of the American Railway Association, the author had given him a copy of the minutes of proceedings of their last meeting held at the Hotel Brunswick, New York, in April last.

This paper is already longer than the author originally intended, but there appears to be such a diversity of opinion in the Association in relation to the use of a distance signal; and further, a distinction suggested to be drawn between what is called the telegraphic block system and the controlled manual and automatic block systems, in relation to distance signals, that it would occupy too much space here to discuss the questions raised; but in any discussion which may follow the reading of this paper the author respectfully suggests that these questions might be included.

Single Line Working.—Any paper on block working is certainly not complete without an exhaustive treatment on this subject. Correct block working on single-line railroads is far more essential than on double-line railroads, for in the former all forms of collision are likely to occur. The subject is, however, too extensive and important to be lightly dealt with now, and the author must leave it to others better entitled to describe its operation than himself; or leave it for another occasion, when he might venture to set forth a few points worthy of discussion.

Signal Replacers.—In the majority of the systems of "lock and block" which are now appealing to the public, some system of automatically replacing the section signal in any section to "danger" on the passage of a train out of that section, is considered essential.

It is, of course, understood that the idea of automatically replacing the sectional signal to "danger" is comparatively old, and that there have been many schemes before the railways for effecting this, but, so far as the author is aware, all the schemes are open to the objection that the engagement between the two portions of the upright rod to the balance lever and the arm is made and maintained by the electric current, and consequently there is, first, a sudden wrench on the armature when the signal is pulled off, and during the time of remaining off a steady strain (more or less according to the design) on the armature. There is a considerable strain on the Lattig, less in the Hambay, and less still in the Coleman,

but, however little the strain on the armature may be, the author submits that the principle in all of these is wrong. The electric current should only be used as the means of engaging the apparatus, and the strain caused by pulling the signal off and maintaining it in that position should be borne mechanically.

For the better understanding of the differences between the methods of signaling trains with the single-needle instrument and the semaphore and similar instruments, the author proposes to follow, in each case, the signaling of an express train through a block section.

Taking the case of the single-needle instrument first, and assuming two sections, A and B, and a train approaching A from the rear: A rings once on the bell to call B's attention, B intimates he is attending by repeating the signal to A; A then gives what is commonly known as the "be ready" signal, four beats on the bell, which B acknowledges by repeating. A intimates the acknowledgment is correct by giving one beat of the needle to the right, and B then pegs the needle to "line clear." When the train has passed A's post and is about to enter B's section, A again calls B's attention by one beat on the bell, which B acknowledges by repeating as before. A then gives two beats on the bell to B, indicating "train on line." B repeats and unpegs the needle, A acknowledges correct repetition by one beat of the needle to the right, and gives the descriptive portion of the "train on line" signal, two beats of the needle to the left. These are repeated by B, A acknowledges correct repetition by one beat of the needle to the right, and B then pegs the needle over to "train on line." When the train passes B with tail lamp or board on the last vehicle, B calls A's attention by one beat on the bell which A repeats, B then unpegs the needle and gives the "train out of section" signal, two beats of the needle to the right, A repeats this signal, and B acknowledges the correct repetition by one beat of the needle to the right, and then allows the needle to resume the normal (vertical) position.

Taking now the case of semaphore and other similar instruments and the same conditions as regards sections, and a train approaching A: A will give the warning (be ready) signal to B on the bell, two beats, pause, two beats; this is acknowledged by B by one beat on the bell. B then plunges, which raises the miniature semaphore at A, and indicates at B "train on." When the train has passed A's post and is about to enter B's section, A gives the "departure" (train on line)

signal, two beats on the bell, and B acknowledges this signal by one beat on the bell. When the train passes B with tail lamp or board on the last vehicle, B gives the "all clear" (train out of section) signal, three beats on the bell, and A acknowledges it by one beat on the bell, the miniature semaphore arm at A is caused to return to the "safety" (normal) position by the putting back of the starting signal lever at B, which can only by done completely when the train has passed over the treadle in advance of the starting signal at B.

Although block signaling with the semaphore instrument is simpler than with the single-needle instrument, block signaling with the latter is not so complicated as the description would make it appear, and it is incomparably better with regard to the possibility of mistakes being made in the interpretation of the signal; and where it is necessary to indicate the route and description of trains, the single-needle instrument, in combination with the bell, lends itself to the purpose much better than the semaphore and similar instruments; in fact, it is within the author's knowledge that these instruments have to be supplemented with single-needle instruments to be used for the purpose of describing trains alone; and as the opinion of the majority in England favors the use of the single-needle instrument, which is conclusively proved by its adoption by the most important railways, probably it is only necessary to adapt it to a "lock and block" system to make such system the "lock and block" system of the future. Upon this phase of the subject the author cannot, at present, enlarge.

DISCUSSION.

DESMOND FITZGERALD, M. Am. Soc. C. E.—One question; you have been over a large number of railroads in this country; would you mind saying where you consider the best combination system in this country is found?

Mr. O'DONNELL.—The best illustrated is on the New York Central road. A combined use of the block system and the interlocking system is necessary, and the best system is a union between the two. There is only one road in this country that has the interlocking and the block in combination, that is the New York Central.

FOSTER CROWELL, M. Am. Soc. C. E.—I would like to ask Mr. O'Donnell in regard to systems other than those he has described,

which are all based on the principle of visual signals. There are some systems, or some devices, coming into notice in which the visual signal is entirely dispensed with.

Mr. O'DONNELL.—I gather you refer to the Kinsman block system. That proposes to entirely eliminate signals of all grades, but relies practically on the fact that, while there may be a signal directing a movement, if the train passes it at "danger," it is automatically stopped. That necessitates an addition to the locomotive. We have had trials of similar systems and many endeavors to have them adopted, but I do not think you will find superintendents in this country ever take sufficient interest in signaling to alter their locomotives.

Mr. CROWELL.—The system is on trial, in regular service, on the Chicago, Milwaukee and St. Paul Railroad, and possibly some of the officials of that road are here and can give us some information as to the success of the operation. The attachment which Mr. O'Donnell has alluded to as being necessary to the locomotive, is of such trifling and inexpensive character that it does not militate against the system in the least. There may be other reasons.

Mr. O'DONNELL.—There is one other which occurs to me, and that is, if you rely absolutely on some such system and the engineer of the train comes to disregard his signals, expecting that even if he does pass them at "danger" he will be stopped, if a collision should occur, it becomes a serious question; the signal becomes under those conditions of secondary importance.

Mr. CROWELL.—I am not here in any way to represent any system or theory, but I should like to point out that Mr. O'Donnell has emphasized the importance of a system of signals not based on color nor on form, but on position, so as to avoid, as far as possible, any likelihood of the man running the engine either failing to see the signal or misinterpreting it.

His failure to see the signal may be due to his eyesight, or to fog or to other causes. If he fails to see the signal, the signal might as well not be there. Some very disastrous accidents have occurred in this country, due to the impossibility of seeing a visual signal. I understand that there has been an impetus given to the effort to supply the place of a visual signal, and the automatic Kinsman system and other devices have been suggested on that account.

The Kinsman system, in addition to affording a means of stopping a train in case of the disability of the engineman to see the signal or to comprehend it properly, has the facility for doing more than merely providing block signals. In addition it also operates in connection with open switches, misplaced or unlocked switches, or partly open draw bridges—all track interruptions, in fact, are taken care of by the Kinsman system—so that, not only alone, but also as an auxiliary to any

other system, it would have uses. It is a system in its infancy, and it is so startling in its departure from the old preconceived notions that the engine driver must see the signal, that at first it does not recommend itself. The practical application of any system is the test. The system applies both to double-track and single-track roads, and there has been found great difficulty in the way of applying the block system to a single-track road with visual signals. I here want to thank Mr. O'Donnell for the comprehensiveness with which he has outlined these different systems. The ability to use visual signals with the Ki nsman system is quite evident. Mr. O'Donnell has called attention to the fact that in case visual signals were used in connection with the Kinsman system, the engine driver might get careless; but I think experience proves the reverse.

Mr. O'DONNELL.—I would like to ask Mr. Crowell one question. Does the Kinsman system provide for the operation of the distant signal? It is the only signal the driver can pass both at danger and safety. I understand the Kinsman system stops him at danger.

Mr. CROWELL.—The Kinsman system stops him without reference to the position of the distant signal; in other words, there is a multiplication of signals, and the principle of the connection with the distant signal is not contemplated. I, perhaps, am going a little too far. I ought not to say anything which represents the Kinsman system. I am only giving my knowledge of it. The same principle can be applied with an indicator signal, and the wiring of the Kinsman system could be extended to the distant signal as such if desired. There is a modification of the system by which it can be known to the engineman whether he is stopped in advance or by an overlapping danger from the rear. On a single-track road he thus knows whether he is stopped from a danger ahead or from behind, which is quite important.

The question you have asked, so far as I am able to answer it, is very simple. The Kinsman system, in itself, does not necessarily involve the use of the distant signal at all; but if it is desired, the application is easy by a simple extension of rules.

Mr. O'DONNELL.—If the distant signal is accomplished, it seems to be the rear home signal. You may accomplish the signaling and treat the distant signal as a home signal, but that does not allow the man to creep up to the home signal and know what the condition of the line at the home signal is. I have not studied the Kinsman system. You raised one question in connection with single lines.

With the tablet or electric train staff systems, the withdrawal of either the tablet or the staff from the instrument automatically breaks down the block system, but I have for some years repeatedly pointed out that the Sykes lock and block system, if properly carried out, is just as good on single-track roads as on double-track roads, the idea being to maintain a space interval between trains absolutely. If

it is considered that the traffic would be too much hampered on single-track roads by preventing a second train in the same direction until the first train had cleared the section, then a permissive staff system could be employed, which would allow one or more trains in the same direction, but no train in the opposite direction until the last train has arrived at the section to which it is running.

There are certain conditions which would be necessary in carrying out this system, but it is very cheap, easy in working, and a complete block system, and hedged round with conditions by which a great amount of safety can be obtained. The head-on collision is absolutely prevented, which, after all, is the most serious form of collision, and that more likely to happen on single-track roads than on double.

E. E. RUSSELL TRATMAN, Assoc. M. Am. Soc. C. E.—What does Mr. O'Donnell think of the Black system on the Manhattan Elevated Road, which seems to be practically the same as the Baronowski system (1858) ?

Mr. O'DONNELL.—I am not connected with any system, but I have fundamental objections to all mechanical systems. The Black system is merely a mechanical automatic signal. I have seen two trains many a time on that road when there was no space interval except a few yards between them.

A MEMBER.—I presume that lack of space was due to not carrying out the rules of the system.

Mr. O'DONNELL.—Possibly. The Manhattan Elevated Railroad may be put in the class of railroads which has no margin of space, and so frequent are the trains, possibly they must disregard a block system; certainly a block system is not operative there.

Mr. TRATMAN.—Do they not still have in England a common practice of giving a "section clear, but station blocked" signal, implying that the engineman may run as usual over the block or section, but with the expectation of finding the station signals against him, protecting a train in the station, and thus making a permissive block. In such case does the signalman give any special warning to the engineman? I understand that this rule has led to several accidents.

Mr. O'DONNELL.—He is supposed to caution the engineman, but the rule you quote is frequently condemned by the Board of Trade and is very misleading.

Mr. TRATMAN.—Has not the Board of Trade power to prohibit such practice ?

Mr. O'DONNELL.—I believe it has, but it hesitates to exercise its power unless authorized by Act of Parliament.

H. G. PROUT, M. Am. Soc. C. E.—There is a point raised on page 436 of the paper that is occupying a good deal of the attention of American signal engineers. That is, with reference to the normal danger position of the automatic signal. It is a fundamental principle

in railroad signaling that the normal position of the signal should be danger; the absence of a signal should be a danger signal; the positive signal should be a clear signal. If there is no signal, it should mean danger. But in the introduction of the automatic system on the American railroads, we have run against the difficulty of using the normal danger position for the signal. One, at least, of the companies introducing the automatic system is now putting in its signals to be operated in that way so that they stand normally at danger; but I understand that railroad men, particularly in the West where they have long lines of unobstructed view, base their idea of the automatic signal on the ground that as the engineman approaches the signal, which he may see for a long distance, if it is standing at danger, he does not know whether it is going to be cleared or not, and he does not know whether to reduce speed or not, and this uncertainty will cause delays. I can conceive that it would be an inconvenience for them to abandon the normal clear position; but it seems to be a vital principle in signaling that the normal position of the signal should be at danger, and it would be interesting to hear some discussion on this particular point. Mr. O'Donnell has, I have, no doubt, very decided views on the matter. Mr. Wallace is here now and has had considerable experience with automatic signaling, and he might tell us something interesting on that point.

JOHN F. WALLACE, M. Am. Soc. C. E.—I did not come here intending to discuss this paper. This is a paper prepared by an expert in signal engineering, and we have very few in our society. I do not presume to be one myself, although I have had more or less to do with signals. Mr. O'Donnell takes practically the English standpoint in his paper; any answer to him should be carefully prepared, but I am willing to give, as suggested by Mr. Prout, a description of the signal system on the Illinois Central Railroad which may be of interest to you in this connection.

The road embraces 3 690 miles of line, and of course the larger part of it is composed of branches and outlying lines that a railroad company cannot afford to signal, but we have a modified telegraph block that extends over the whole system. It is what is called the Harrington system; that is, double semaphore arms located at all telegraph stations and are operated by the telegraph operators. Those arms are held at danger normally; when a train approaches the station, and the engineer sees both arms at danger, the engineer calls by whistle for his signal. If the block is clear or no orders await the train, the operator lowers the arm and the train proceeds. On this portion of the road we have no difficulty in reference to the point that Colonel Prout raised. Some of our limited trains run at 40 or 50 miles between stations, and there is no slacking speed for this reason. In the Chicago terminal district, however, a part of which consists of eight tracks,

part of six and part of four, down to a double-track system, we use what is known as the Hall automatic. One district is divided up into two lines for local suburban traffic, the stations being 2 600 ft. apart. Two tracks are given up to through passenger service, the blocks being from 5 000 to 5 600 ft. apart, two to freight and two to fast express suburban service. All junction points are handled by interlocking systems, connected with the automatic block systems. On this section our signals are not operated on the normally danger plan, for the reason that Colonel Prout spoke of.

We desire these trains to run at high speed, and sometimes two or more signals can be seen ahead of the train, so that it would be liable to cause our engineer to diminish the speed of trains if they were operated on the normal danger system. The signals, however, are so fixed and regulated, that should any blockade or failure occur they would go to danger automatically. That is, the normal position of the signal is at danger, but it is held clear by the electric action. Should the electric action fail, or should a switch be left open, etc., the signals would come to danger automatically. We have operated this system for over a year. During the World's Fair period we handled at the terminal stations from 900 to 1 000 engines in 24 hours. We carried in six months 19 500 000 people in round numbers. During that period we had no failures, in the sense that a signal ever showed clear when it should show danger. We did have failures in the sense that through the breakage of the wire or through a short circuit the signals would occasionally go to danger when they should have showed clear. When the system was installed the track circuit was not entirely perfected, but the railroad company had the option of changing to what is called the "track circuit," if they desired. Since that time it has all been changed to track circuit. In that system an open switch between Signal 1 and 2 would change the signal to "danger." The closing of the switch automatically will clear the signal, and in order to prevent the opening of the switch after the train has passed into the block, the switch is provided with indicators and bells, so that after the train has passed into the block the bell begins to ring, and rings until the train has passed out of the block.

This system has given us perfect satisfaction, and has satisfied not only the engineering department, but also all the transportation officers who have used it.

H. B. SEAMAN, M. Am. Soc. C. E.—Has Mr. Wallace any electric trolley road parallel to his line?

Mr. WALLACE.—We have two crossing our line, but during the term before we put the signals into active service we worked them under cover. That is, the disks were shaded, but a small aperture was left so that the signal engineer could see the working of the signals. During that time we had one failure, due to the ground circuit. As

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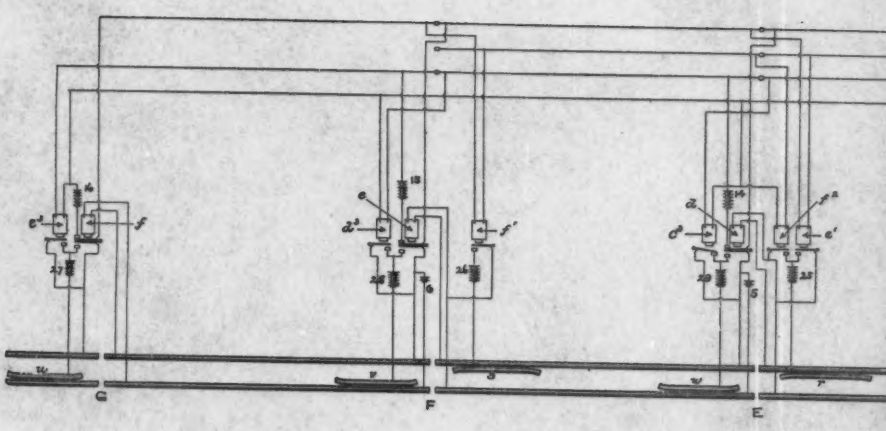

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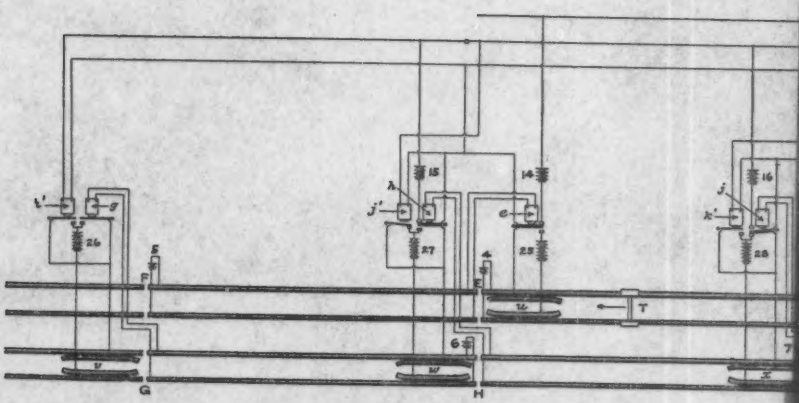
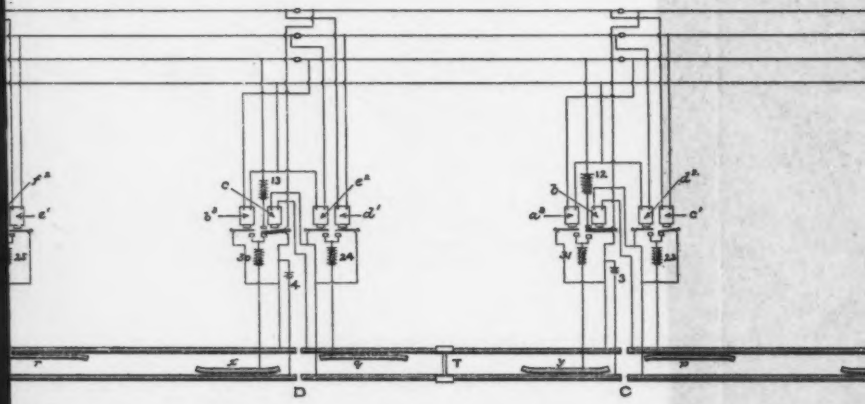


KINSMAN BLOCK SYSTEM CO

ARRANGEMENT OF CIRCUITS FOR SINGLE TRACK ROAD.



ARRANGEMENT OF CIRCUITS FOR DOUBLE TRACK ROAD.

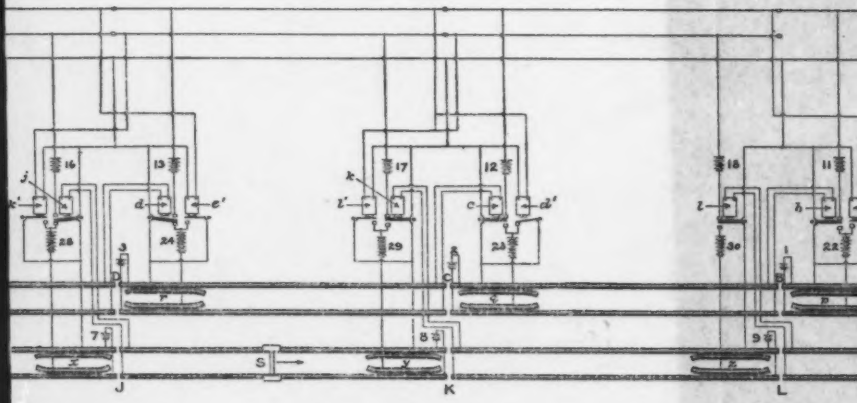
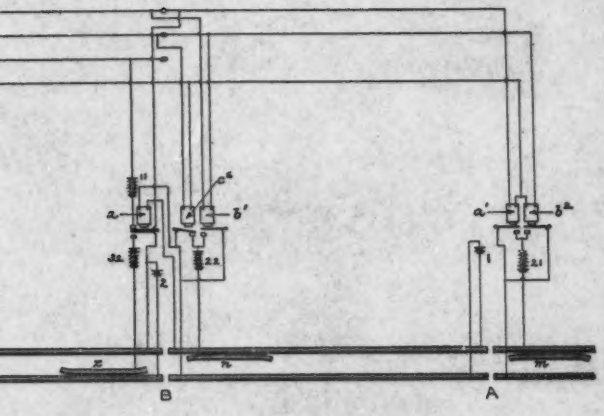
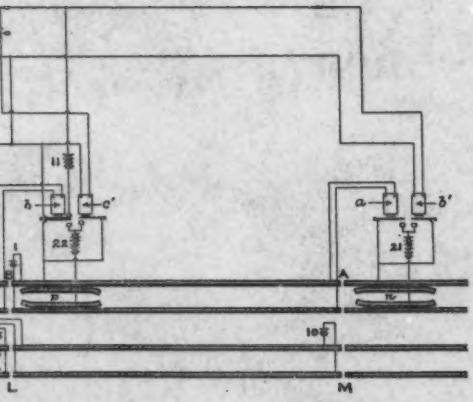


PLATE LXIV.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXXII, No. 738.
CROWELL ON RAILROAD SIGNALING.





I understand the case, as reported to us by one of the signal engineers, the circuit in the rail was very slight and the leakage of the ground current from an electric road crossing our rails caused a short circuit, and we had considerable trouble until we cut out a short section of track for about 25 ft. on each side of this crossing and connected the rails by wires past this crossing.

In reference to the disk form of signal which Mr. O'Donnell mentions, at the last meeting of the Railway Association an effort was made to establish the semaphore signal as the standard, excluding all others. The Railway Superintendents' Association, I understand, decided that either form was allowable. The reason the Illinois Central adopted the disk signal was this—we found it necessary for practical, as well as economical, reasons to use an automatic signal. We had to choose between an automatic pneumatic, controlled by one company, and the disk controlled by another. The automatic semaphores applied to block signals require a great deal of care. We chose the disk in the first place because it was enclosed in a case, it was protected from the air and operated by gravity, and it was considered that it would give less trouble in maintenance, and we saw nothing that would cause it to go to safety when it should show danger. Our interlocking plants are situated at junction points and connections, and the tracks protected by semaphore signals and derails. An engineman running by these signals is immediately derailed. We desire that the signals used in any way permissively should be of a different character from the absolute stop signal of the semaphore.

I would like to say one word with regard to the Kinsman system. It is this. The main objection that I see to it, from a practical standpoint is, while the amount of money that would be necessary to expend if it were affixed to one individual locomotive is small, yet when you attempt to apply it to a line it would be a matter of great expense. Take our road. On our terminal line we have engines that come over the Michigan Central and the Big Four road. We are liable to bring engines into our general repair shops for repair from all the outlying districts. In order to use a block system of that character we would have to have not only all locomotives in daily use on this section provided with it, but also all the other locomotives; and in a busy terminal like Chicago, there is a liability at any time to have freight and other locomotives running over those tracks belonging to any railroad entering the city. That, it seems to me, is the greatest objection to the system.

A MEMBER.—I would like to ask Mr. Wallace if they had any trouble with their disk signals, due to snow storms and sleet?

Mr. WALLACE.—During last winter we had a great many storms, and there was only one time that we had any trouble from sleet.

A MEMBER.—Did it not obscure the color?

Mr. WALLACE.—No, not entirely.

Mr. O'DONNELL.—There was one question which Mr. Prout raised and which Mr. Wallace corroborated; that is, with reference to the use of the normal safety position of the system on the Illinois Central. The point was raised that drivers, if the position was "danger," might possibly hesitate as to whether it was to be drawn off and would not know whether to slacken speed. It occurs to me that that might be overcome if you overlap your sections, make Section 1 automatically lower Section 3; when he comes to Section 3 he is held, and so 1, 3, 2, 4 throughout the line, the signal to lower before he comes into the section.

There was one question which Mr. Wallace raised, which was, as he stated, the question between the promoters of one form of signal and the promoters of another. Of course, there are other signals in the market which have the normal danger position and the semaphore arm, as on the New Jersey Central to-day.

Mr. TRATMAN.—I do not see any reference in Mr. O'Donnell's paper to the Mozier system, which is in use on about 1 000 miles in this country, and differs from most other manual systems in being controlled by the train dispatcher. Thus, while in ordinary systems the orders are transmitted from one block signal tower to the other (as *A* to *B*, *B* to *C*, *C* to *D*, etc.), in the Mozier system they are transmitted from the dispatcher's office to the operator in each tower successively (as *X* to *A*, *X* to *B*, *X* to *C*, etc.).

Mr. O'DONNELL.—My paper is already too long, and if I were to include all the various systems which promoters have introduced, it would be a considerable book.

Mr. Wallace mentioned the semaphore arm outside of the block system, which is operated manually.

Mr. WALLACE.—The Harrington system. It is a combination system, so far as dispatching the trains is concerned.

Mr. O'DONNELL.—The New York Central, which is operated by the operator, has the manual signal, which is in front of him.

Mr. WALLACE.—Yes.

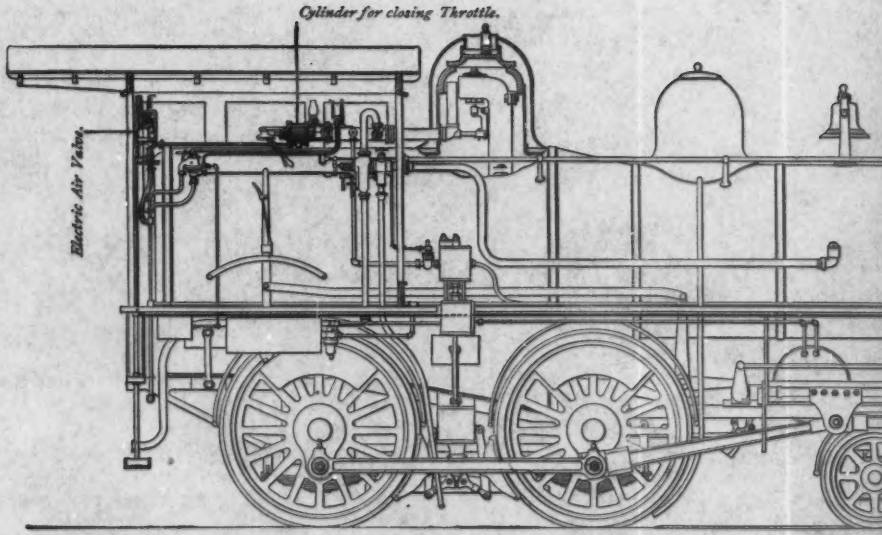
Mr. O'DONNELL.—The fact of his being a train dispatcher does not interlock the two.

Mr. WALLACE.—There is no interlocking of signals in this system.

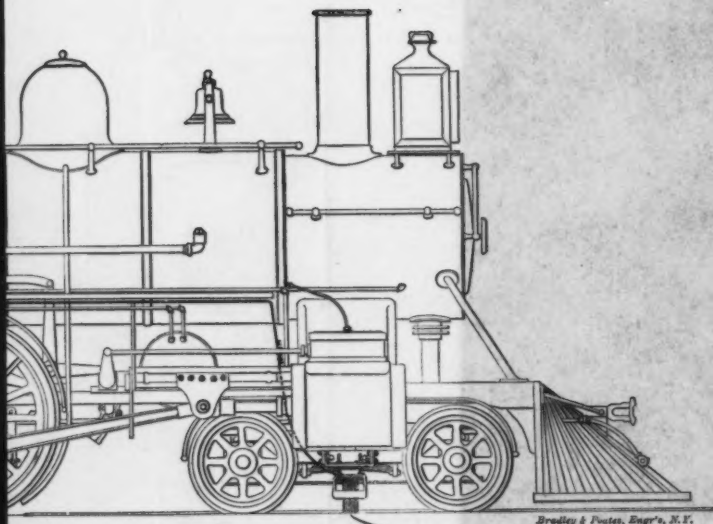
J. RAMSEY, Jr., M. Am. Soc. C. E.—He may tie his signal down. It is simply the operator giving a signal for a train to enter the block between his station and the next.

Mr. O'DONNELL.—Unfortunately, the signal is placed in the middle of the section.

Mr. RAMSEY.—Mr. Wallace referred to the action of the Railway Association. The largest portion of the discussions at the April meeting was on the signal question. The Association idea was simply



LOCOMOTIVE EQUIPMENT OF THE KINSMAN BLOCK



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to adopt three general divisions of signaling; one, the station signaling, which we have just referred to; the other a manually controlled signal, and the third class the automatically controlled signal. A large majority of the railroads voted in favor of the semaphore arm as against the disk signal. Further than that they did not go. They referred the whole question back to the committee, and there the matter remained.

One of the questions was as to the proper light for safety, whether it should be white or green? If the red lens is broken, the safety signal is shown (no matter what block system is used), so long as the white light is used at night, so that there may be a safety signal given when the danger signal is intended. On account of determining the proper color for safety signal more than anything else, the whole matter was referred back to the committee.

Mr. O'DONNELL.—There has been a great deal of discussion in relation to the colors, but in the British Board of Trade it has been decided that white is the danger signal. In this country you have adopted the green for the danger position, and, therefore, you have to find a substitute if you put green as the "all-right" signal.

Mr. RAMSEY.—White can be used as a caution signal.

Mr. O'DONNELL.—No, white should be used as danger. Perhaps Mr. Crowell will give us some further information about the Kinsman system.

Mr. CROWELL.—It will give me great pleasure to do so; and first it may not be out of place for me, in as few words as possible, to define the Kinsman system. It is a system of automatically stopping a train in the face of danger through the agency of electricity. The cause which may stop a train may be an approaching or standing train within the block, or it may be a train or an engine or a car on the track not within that block, but within an adjacent block or a block removed two spaces away, or as many spaces as may be desired. The communication between the block and the train to be protected is by wire connection, and may be of any convenient length; usually it divides the road into blocks of track, protecting every alternate block as well as the adjoining block; that is, each block is protected from the second block away, either before or behind, and also from the adjacent blocks (see Plate LXIV). The protection is, 1st, from a standing or moving train on the track; 2d, from an open drawbridge, or any break in the continuation of the rail; 3d, also from any open or unlocked switch, for the wiring may be so arranged that unless the bar which locks the switch is completely closed, the operation of the system is just as perfect as if the switch is open. The system is based on an original departure from all systems of visual signals. In a proper sense, it is not a signal system at all, although it can be worked in combination with a signal system and signals can be used. It operates as follows:

The train, in approaching a protected point, passes over and in contact with (see Plate LXIV) two ordinary guard rails, which may be set at the regulation distance from the main rails. The locomotive is provided with a contact brush (see Plate LXV), which travels within the flangeway of the forward truck. On reaching a contact point, if the guard rails are energized by an electric current, the communication between the guard rails and the locomotive is set up and the operation follows. If there is no energy in those guard rails there is no operation whatever of the apparatus. To energize those guard rails a current comes from a relay battery, which is placed in a convenient position near the contact, usually so that the connection between the relay and that point is a very short one; the connections from battery to contacts are protected, and, in order to guard against the accidental interruption of the relay, the latter may be in duplicate or in triplicate. The relay is arranged so that the energizing current proceeds from the battery to the guard rails whenever an armature is dropped in the battery box; that armature is connected with the track circuit and dropped by short circuiting or by disruption of the circuit. Provision is made for two automatic actions of the devices before the "section" in which the cause of action exists is reached, thus always preserving one clear "section" of track between an approaching train and the point of actual danger. If there is an obstacle on the track, any break in the continuity of the track or any other cause of danger, the armature drops in the battery box, operating the guard-rail circuits in adjoining sections. When the energizing current is in force, the brush attached to the locomotive and moving in the flangeway comes in contact with the guard rails, and the current passes through the wiring of the locomotive (see Plate LXVI) to an electric air valve placed in the cab. When the energizing current reaches it, the valve is opened and communication established between the train pipe of the ordinary air-brake apparatus, and a cylinder (Plates LXVI and LXVII) placed around the valve stem which controls the throttle of the engine. The admission of the air to this cylinder starts the valve stem, and, immediately after starting, communication is made with the open air, so that the automatic action of the brake is at once set up. In other words, the instant that the contact brushes on the engine pass the contact position, the current shuts the throttle and sets the air brake. No change has been made in the usual methods of operating the steam or air valves; in fact, if the apparatus was enclosed no change would be noticeable to the engineer until such time as he failed to see and obey the danger signal or other cause which required a reduction of speed or a full stop. Neither does this arrangement prevent his obeying a visual signal in the ordinary way, should he have occasion for so doing.

The operation that takes place in the cab is precisely that always

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LOCOMOTIVE EQUIPMENT OF THE
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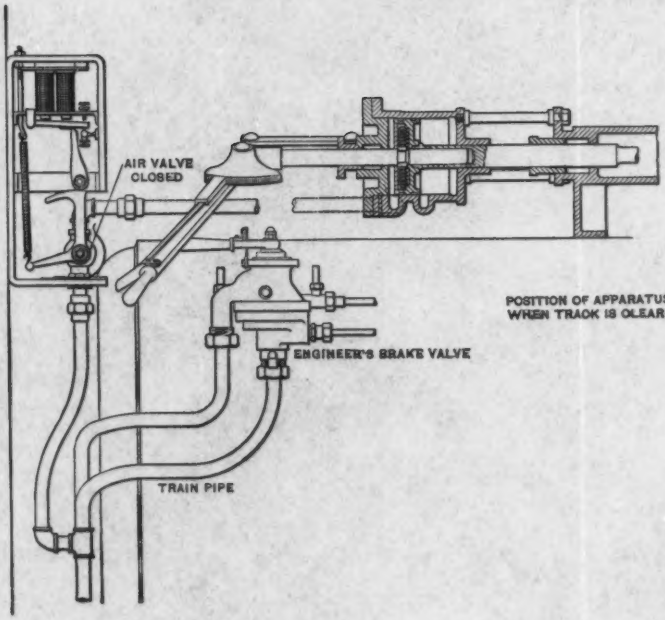

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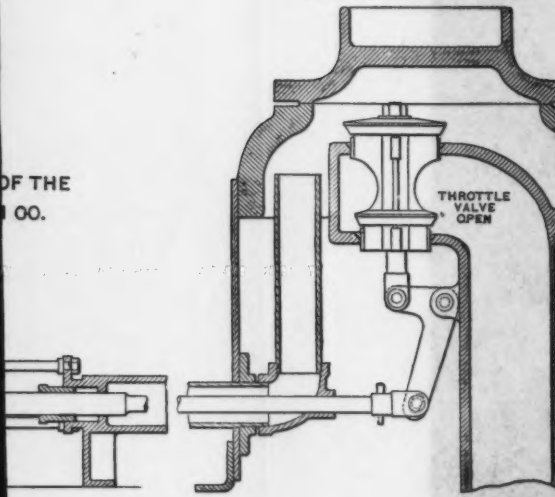

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POSITION OF APPARATUS
WHEN TRACK IS CLEAR

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performed by an engineer when he "slows down" or makes an ordinary stop, no more, no less; that is, the shutting off of the steam by closing the throttle valve and the setting of the air brakes by releasing the air from the air-brake system.

However, should it be inconvenient for the engine driver to stop at that point, or should it not be required of him to do so, or should he wish to treat this stop as a distant signal and run to the end of his block before coming to a stop, he can immediately open the throttle again and release the brakes.

The means by which that is brought about involves only a very simple addition to the locomotive. A new engine, of course, can be built in such a way that the appliance can be in any desired form; but on an old one a small cylinder is put on the end of the boiler, projecting out 12 or 14 ins. to the rear (see Plates LXVII and LXVIII), surrounds the lengthened-out valve stem. The usual throttle lever is used; the throttle lever, however, is connected to the stem through the medium of an automatic clutch, so that the valve stem will work without carrying the lever with it in case of an energizing, but the lever always will move the valve stem. The apparatus, therefore, which is used on the engine, is extremely simple and inexpensive; it is not subject to great wear and will last a long time. The additional cost of fitting up a locomotive with a cylinder is small. Plate LXVIII is a view of a working model showing locomotive equipment in actual relation. *A* is the throttle-stem cylinder, *B* represents the boiler end, *C* is the electric air valve, *V* the ordinary engineer's brake valve, and *T* the throttle.

In this way I reply to the objections raised by Mr. Wallace. Also as to the statement that were the system used on one line it would be an embarrassment not to have it applied to foreign locomotives that might pass over that line, the answer is that the expense is light enough to make that objection unimportant. No more objection attaches to that than to the different couplings now in use. For instance, our train from New York over the Lehigh Valley Road had cars with one style of couplers; on some of the cars from Philadelphia there was another style; and still another is in use on the Reading road, so that a change of coupler heads was necessary *en route*. That is an illustration that that kind of an objection is not a serious one if you are trying to get an ideally perfect system.

The application of the Kinsman system to the block system of stopping trains is therefore possible, whether you use it for the absolute block, connecting two successive blocks, or intermediate blocks, or blocks any distance apart. If it is desired to maintain the visual system in connection with it, it is quite possible to adopt the signal too. If it is desired to retain the principles of home and distant signals, the same arrangement is possible. It can accomplish all that the visual

system accomplishes, and it can accomplish also the protections which the block visual signals cannot, that Mr. Wallace has referred to.

The absence of the necessity of looking out for a signal is a startling one when we first regard it, but when we consider that the most prolific cause of danger and accident is the failure to observe a signal, it is a recommendation for a system that it can be dispensed with.

I will only add that the Kinsman system has passed its experimental stage and has been in successful operation on one of the divisions of the Chicago, Milwaukee and St. Paul road for a number of months. I am not in any way connected with, or responsible for, the system. I, however, superintended, as consulting engineer, the practical tests of the system in its inception and have watched its results with great care.

Mr. O'DONNELL.—I do not propose to reply in detail now to Mr. Crowell, because I think it would be better to do so when the matter comes to me in regular course, as the meeting is now already rather prolonged. But there are one or two points which Mr. Crowell has raised in which he refers to an objection of mine in connection with the Kinsman system; that is, the obviating the necessity of looking for the signal. I think that is a point in the wrong direction. It is giving the engineman an opportunity for carelessness. In the course of this paper I have given my views on automatic signaling, and I conclude the Kinsman system in practically an automatic system, so that my reasonings in the paper refer to the Kinsman system.

I gather that the Kinsman should be used as an auxiliary to the ordinary signaling. I gather also there must be some sort of interlocking to lock a switch; therefore, you will have all the difficulties of interlocking of the ordinary crossings of points, and in case a train was shunted onto a siding and stood there for an hour or two, every difficulty that is met with in the ordinary signaling will be met with in this case.

I would like to ask a question: About what is the distance at which a train can be brought to a stand?

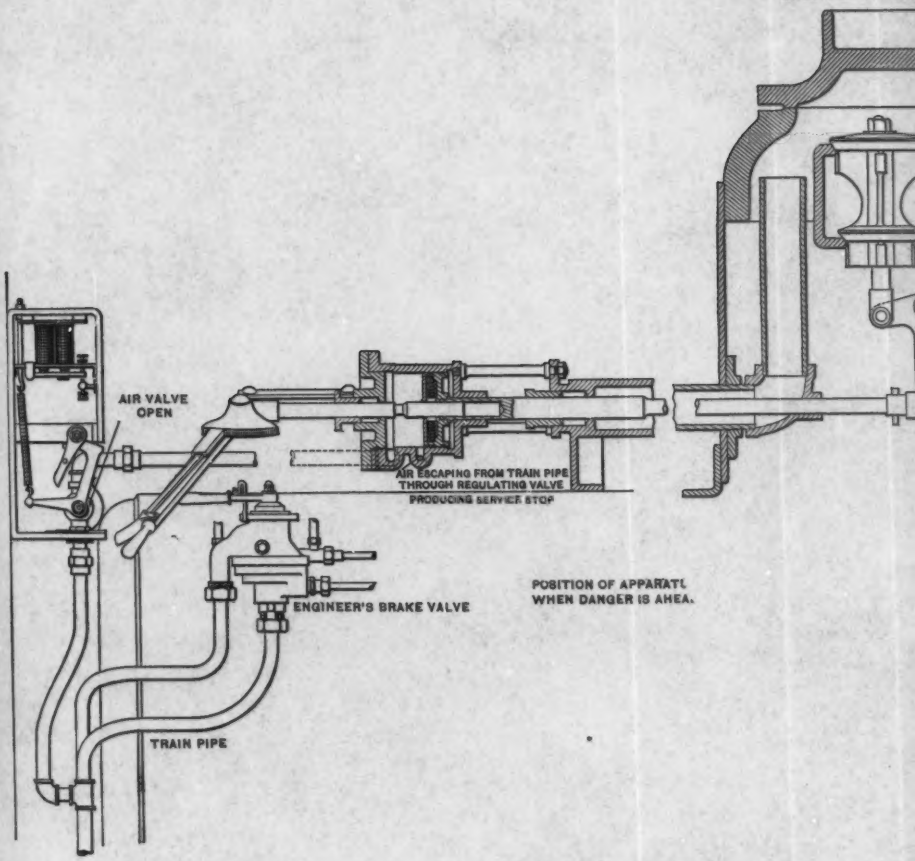
Mr. CROWELL.—That distance is not fixed; that is to say, they can have the contact at any point that may be selected. That can be any distance, speaking reasonably, of wiring.

Mr. O'DONNELL.—My meaning is somewhat different. Immediately the operation on the throttle valve is performed, to what distance would the train travel before it came to a stand?

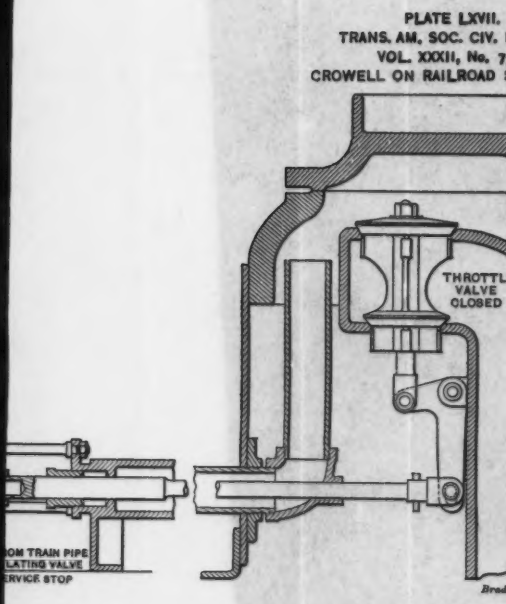
Mr. CROWELL.—That would depend on the speed of the train.

Mr. O'DONNELL.—Take the Empire State Express.

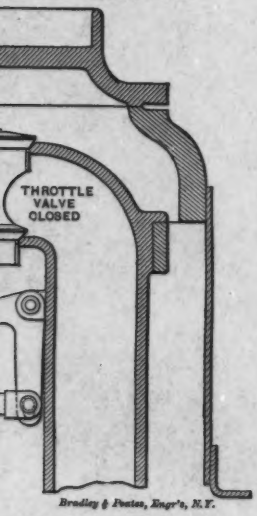
Mr. CROWELL.—It can be regulated to apply to an emergency stop, or it can be used for a gradual stop; the ordinary practice would be a gradual stop, for the reason that you always have a vacant block between your protected block and the block in which the danger is; the



POSITION OF APPARATU
WHEN DANGER IS AHEA.



POSITION OF APPARATU
WHEN DANGER IS AHEA.



Bradley & Foster, Engr's, N.Y.

system is so wired that you cannot emerge from that block without being again stopped.

In regard to interlocking I will say my remark was made in regard to any ordinary switch; not necessarily to an interlocked, but to an unlocked, switch.

Mr. O'Donnell.—We use a similar thing in our system. I asked you the question regarding the distance because Mr. Voorhees, as you remember, stated it would require 1½ miles before the train would stop. That would not suit a majority of the lines in this country.

Mr. Crowell.—The question of speed is entirely independent of the system signal. If you try to stop the train from a visual signal that is too near the danger, it is of no value. In this case there is always a vacant intermediate block, and the blocks can be of chosen length; if the blocks were, say, one mile in length, you would have always two miles in which to stop before coming to the block in which the danger is. Any two trains, if approaching each other, would mutually be stopped.

Mr. O'Donnell.—As I said before, I will not reply in detail until I get Mr. Crowell's notes.

Mr. Crowell (by letter).—Since the Convention I have obtained through Mr. Wilbur C. Fisk, Assoc. Am. Soc. C. E., General Manager of the Kinsman Block System Company, the subjoined table of statistics of operation of the Chicago, Milwaukee and St. Paul installation above referred to, and also a copy of the railroad company's rules governing its use which will be found interesting and instructive.

The illustrations, Plates LXIV to LXVIII, are furnished by Mr. Fisk, together with the following detailed description of the operation in detail for both single and double-track installations.

The operation in detail of the Kinsman system is, for a single-track road, as follows: If a train, which may be represented by *T'* (Plate LXIV) is in any section, as *C–D;* the current from the track battery 3, which normally passes through the relay *c*, is short-circuited by the wheels and axles of the train, thus allowing the armature of relay *c* to drop, and so completing the circuit of battery 30, with the exception of the space across from guard rail *x* to opposite main rail; in other words, charging guard rail *x*. The dropping of the armature of relay *c* also breaks the circuit of battery 13, which circuit normally passes through relays c^1, c^2 and c^3. Thus by having the circuit operating these relays broken, their armatures drop, and consequently close the circuits of batteries 23, 22 and 29, with the exception of the spaces from guard rails *p*, *n* and *w* across to the main rails opposite. In other words, a train in Section *C–D* causes guard rails *x*, *w*, *p* and *n* to be charged, and when another locomotive strikes any one of these guard rails, the current is carried to its cab and so causes the throttle valve to be shut and the air brakes to be applied.

In the case of a double-track road, the operation is the same, except that the track is protected in one direction only. For instance, a train in Section *D–E* (Plate LXIV) causes current from battery 4 through relay *d* to be short-circuited. Therefore, the armature of relay *d* drops, causing battery 24 to charge guard rails *r*. It also causes current from battery 13 to be broken, therefore allowing armature of relay d^1 to drop, which in turn causes battery 23 to charge guard rails *q*. Also a train in Section *J–K*, as *s*, will cause guard rails *x* and *w* to be charged.

Copy of Rules peculiar to Chicago, Milwaukee and St. Paul Railway.

CHICAGO, April 8th, 1894.

Engineers,

EVANSTON DIVISION:

The Kinsman block system will be put in service on Chicago and Evanston Division, between Lincoln Avenue and Evanston, north bound, and Evanston and Fullerton Avenue, south bound, at 12 o'clock, noon, April 9th, 1894.

Any obstruction within the respective blocks, such as train, car, open switch or broken rail, will cause steam on engine to be shut off and air brake applied when engine or train enters the first block back of block in which obstruction exists, provided obstruction exists at the time engine or train enters block first named.

When your train is stopped by the shutting off of steam and application of air brake by this block system, you will proceed with train under absolute control until obstruction is reached or until you enter block beyond which obstruction existed.

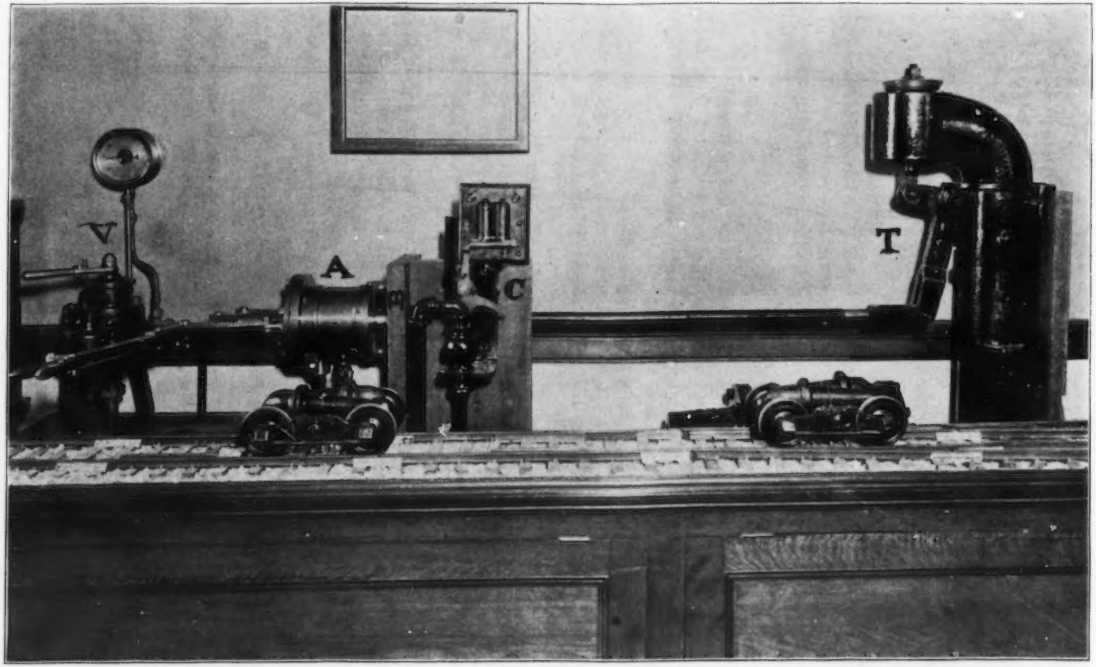
You will make out and send me for each trip, at the end of each day's work, a report, showing application of brakes by this system, on Form 836, which will be supplied at this office.

Engineers will show on this report all cases coming to their knowledge where application of air should have been made under this system, but was not.

(Signed), J. M. BARR,
Superintendent.

Description of plant on the Evanston Division of the Chicago, Milwaukee and St. Paul Railway, and record of its operation from April 9th to August 1st, 1894:

Length of road protected	8.3 miles	
Length of track protected	16.6 "	
Number of blocks	28	
" " switches protected	12	
" " locomotives equipped	7	
" " trains protected	63 952	
" " times "signal" set at danger	127 904	
Application of brakes due to K. B. S		326
Failures in presence of danger		0



Working model showing locomotive equipment in actual relation. *A* is the throttle-stem cylinder, *B* represents the boiler end, *C* is the electric air valve, *V* the ordinary engineer's brake valve, and *T* the throttle.

PLATE LXVIII.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXXII, No. 738.
CROWELL ON RAILROAD SIGNALING.

**Classification of Causes of Stops :*

Trains or cars		145	
Other obstructions		9	
Open switches		4	
Short circuiting (in track circuit) :			
Putting in electric crossing gates	25		
Interference of rods of interlocking plant	10		
Wet slag ballast (chemical action)	16		
		—	51
Broken line wires		20	
Circuit left open by battery cleaner		14	
Defects in new apparatus		54	
Causes not reported		29	
		—	326

E. E. Russell Tratman, Assoc. M. Am. Soc. C. E. (by letter).—Considerable reference has been made in this discussion to the use of systems for shutting off steam and applying the brakes on a train which passes a signal at the "danger" position, and reference has been made to the difficulty of application of such systems at distant signals (which are admissibly passed while at that position) and at switches. A still greater objection is the necessity of having all engines equipped with the apparatus for closing the throttle without, independently of the engineman. This objection would be specially great where engines of other roads are run and on lines near the shops, since every foreign engine and every engine changed from one division to the other or going to the shops would have to be equipped with this apparatus if the system is to be carried out. Mr. Crowell rather makes light of this objection and refers to the changing of car couplers as an instance of the way in which the engine equipment can be fitted. This does not seem to be a fair comparison, as a car coupler is a single individual piece easily and quickly detached and replaced, while the equipment for the automatic arrangement of an engine includes piping and levers, attachments to the throttle rod, etc., which involve shop work. It would evidently be impracticable to place such an equipment upon an engine operating only temporarily (and perhaps at short notice) on a line fitted with this system of signals. It seems to me that such an automatic (or "train-operated") system may be ranked with the ingenious systems occasionally suggested to enable the engineman to operate the switches from his cab. For exchanging of the train staff a train tablet appeared to be a serious objection to the use of either system of blocking for high-

* A number of stops reported in this table are palpably due to unfamiliarity with the system by the maintenance, force and carelessness or ignorance by section gangs, and, as such, are never likely to recur. It is to be observed that all stops were conducive to safety.

speed trains, but investigation shows that in England, Scotland and New South Wales the Webb, Manson and Quirk exchangers are used at speeds of 15 and 30 miles, and for express train service in the latter country. The latter system has a target or lamp hung to the post when the tablet is in position; and in the absence of such signal, or if no tablet is taken off by the "catcher," the engineman will, of course, stop his train. Very little reference has been made to actual practice here in the cancellation of signals, as when a train is admitted to a section and is there perhaps sidetracked for a higher class train to pass. The signalman at the far end of the section has given permission for the first train to enter, and is then required to give permission for another before he has seen the first one clear the block. I am strongly in favor of the semaphore arm as the standard form of signal, and of using an automatic arrangement (operated by the train) for putting the signal at danger as soon as a train has entered the block, and locking it in that position until the block is clear, manual operation being then required to lower the signal to indicate "track clear" for another train.

BENTLEY D. HASELL, M. Am. Soc. C. E. (by letter).—As sickness prevented me from being present when Mr. O'Donnell's paper on Railroad Signaling was read, I beg leave to refer briefly to the article, and the subject on which it treats.

It is to be regretted that Mr. O'Donnell felt compelled to cut short his able and instructive paper on Railroad Signaling, just at the point where block signals must start in the future, viz., Signal Line Working. As about 90% of the railroads in this country are single-track roads, any system hereafter seeking favors must essentially be a single-track signal which will operate equally well on double tracks.

While it is admitted that the systems now in actual use are far from perfect, and fall short of being absolute, and while they seem to cover the field and meet the requirements of the art in a great measure for double lines, they are none of them adapted to single tracks. The reasons for this are many and need not be discussed here, further than to mention the principal objection, which is the cost of installation and maintenance. Any opinion, therefore, on the subject expressed by such an authority as Mr. O'Donnell would naturally start a wide discussion, and result in bringing to the front views of signal experts which would tend to harmonize the many divergent opinions now held and be of great benefit, not only to "contracting companies," but to railroads as well. Consequently, I hope he will find it convenient to write another paper on this particular branch of signal practice at an early day.

The impression conveyed by Mr. O'Donnell, and, in fact, the almost universal opinion, seems to be that an adequate system of block signals for single-track lines has not yet been devised.

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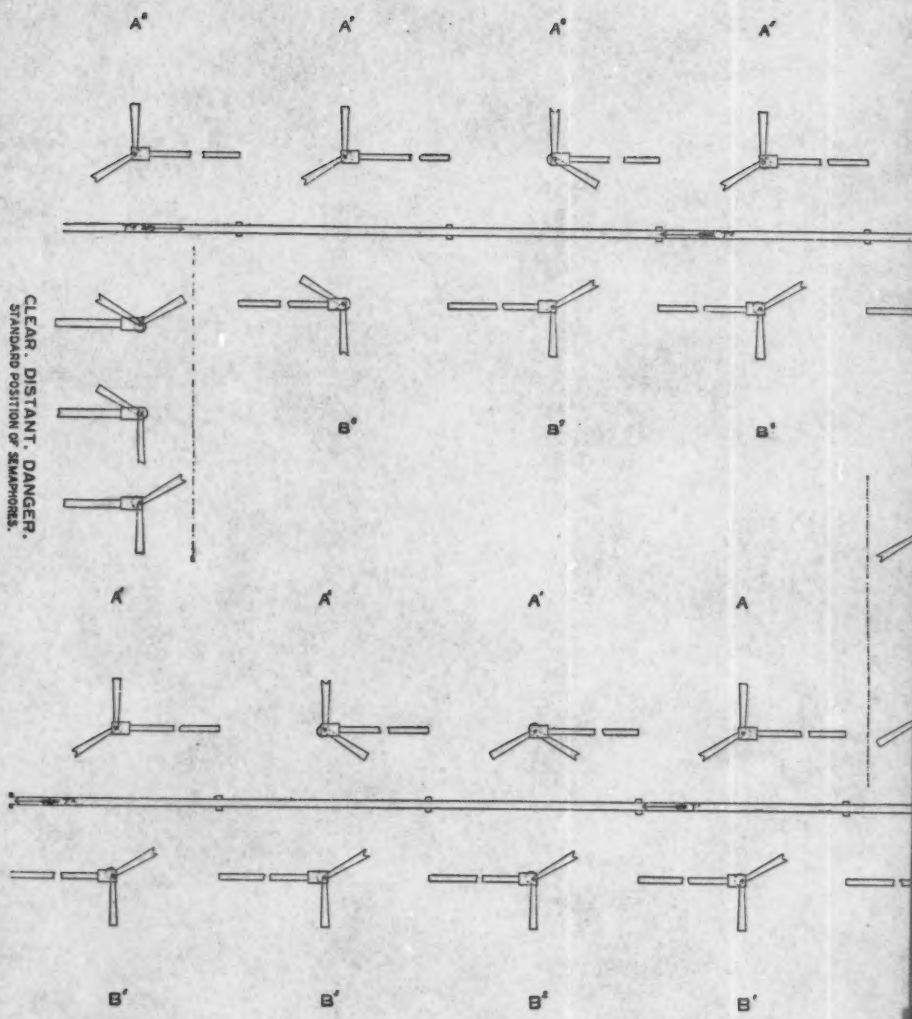
HASELI



CLEAR. DISTANT. DANGER.
STANDARD POSITION OF SEMAPHORES.

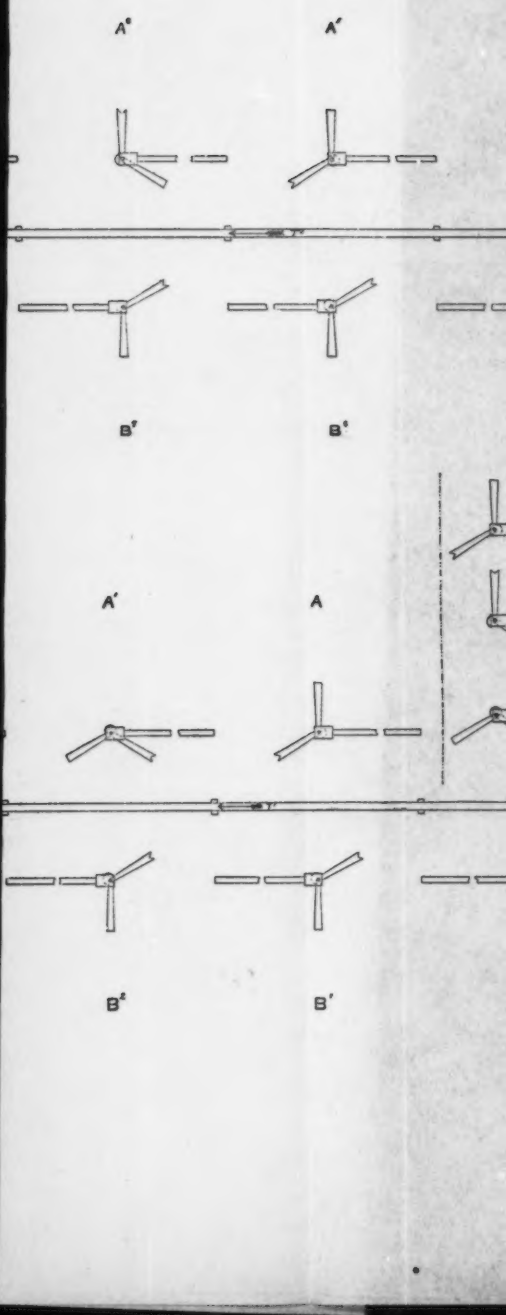

A°
A'
B'
B°
A'
A
B²
B'

PLATE LXIX.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXXII, No. 738.
HASELL ON RAILROAD SIGNALING.

CLEAR. DISTANT. DANGER.
STANDARD POSITION OF SEMAPHORES.

In this I must dissent, for I have seen a working model (full signal apparatus) of four complete blocks, operated with track circuits, on the normal danger plan, and which system seems to possess all the requisites necessary for the perfect protection against rear or header collisions, as well as against broken rails, trains breaking in two, open switches, or other obstructions, and when the first wheel of the train, in passing, sets the header signal, and the last wheel over sets the rear signal. This system I will now briefly describe, as I have seen it thoroughly tested by running cars, and placing them and the tracks and switches in every conceivable position. The signals have always responded promptly and correctly, following each other into and out of an exposed position.

The principal features claimed are, that it is simple, positive in action, absolute, economical in maintenance and installation, form, for both day and night (color only as an auxiliary), and that the use and dependence upon electricity is reduced to a minimum.

Plate LXIX shows the positions and operation of semaphores in this system of single-track roads.

This system of signals is arranged in series, connected by track circuits, each series serving as rear signals and header signals, according to the direction in which the train is moving. The one series serving as rear signals, when the other is serving as header signals. The several operations are accomplished in about the following manner.

The diagram shows trains T^1, T^2, T^3 following each other on single track and train T^4 approaching from opposite direction. Train T^3 is intermediate of signals A^5 and A^6 (which are the signals for train passing from right to left), and has locked signal A^5 to "danger"; A^6 has gone to "caution" or "distant," thereby locking B^6 and B^7 at "danger," and B^8 locked so that it cannot pass "caution," which position it takes on the approach of train T^4, which train in turn locks signal A^7 at "danger"; so that both trains are at once apprised that the point of danger is at signal post A^7 and B^7. No time is lost in sending out flagmen. Had there been no obstruction intermediate of signals A^8 and A^9, signal A^6 would have shown "clear."

The second operation shows a train T^2 following T^3. When it reaches signal A^4, it is found locked at "caution" by train T^3, the home signal being A^5 for train T^2.

The third operation shows train T^1 just passing signal A, section intermediate of A^1 and A^2 being "clear," signal A^1 shows "all clear." When train T^1 passes A^1, A^2 will show "caution" in same manner as described in second operation. Signals always assume their normal position of "danger" when train passes. The first wheel over sets the header; and the last over, sets the rear. The setting of a signal at "clear" has the same effect as a train on a section. For instance, as long as signal A^1 stands at "clear," A, B^1 and B^2 will re-

main locked at "danger"; and B^1 locked so that it cannot pass "caution." Therefore, it is seen that no auxiliary signals (such as torpedoes, flagmen, etc.) are necessary; and no possible combination of circumstances can bring about a "clear" signal when it ought to be "danger" or "caution."

In this system, there is no strain on the armature of magnets, as electricity is only used for a fraction of a second and then only to trip the power. The arrangement of the semaphore blades (see drawing) is such that the signal can never be misunderstood, as form is the essential feature. Color is not necessary by day, except as a concession to custom. At night, the lights are so arranged, with such colors as are desired, as to show one light for "danger," two for "caution," and three for "all clear," or, if preferred by the railroad company, a fixed light with disappearing spectacles of different colors brought into position by the respective arms for which they are intended.

In this description I have tried to be as brief as possible, and consequently many points of detail have been left out. I think, however, sufficient has been said to convince all that a decided step has been taken in the right direction, and my opinion is, that no signal not fully covering the points outlined in this article will ever hereafter receive serious consideration.

Mr. O'Donnell (by letter).—There is considerable force in the remarks of Mr. B. D. Hasell in his written contribution to this discussion: "That it is to be regretted that the author felt compelled to cut short his paper on Railway Signaling just at the point where block signals must start in the future, namely, single-line working."

On page 451 of my paper I said that any paper on block working is certainly not complete without an exhaustive treatment of single-line working, and, further, that the subject was too extensive and important to be lightly dealt with, and that the matter would have to be left for another occasion.

Undoubtedly, single-line working is of far more consequence, so far as the safety and the results obtained from it are concerned, than double-line working, from the simple fact that head-on collisions are liable on single-line roads, and although possible on double lines, still, they are not probable. Moreover, bearing in mind that 90% of the railroads of the United States are single-track roads, it is undoubtedly the case that signaling for such single lines should have more serious consideration than heretofore, in view of the further opportunities for collisions.

Should no other member of this Society take in hand a paper on block working for single-line railroads, I would be pleased to do so on a future occasion.

The discussion on my paper drifted into an explanation of the merits and advantages of new automatic systems appealing to the public. I regret to say that there was very little discussion on the points raised

in my paper, with the exception of one, which is certainly an important one, and that is, the normal position of the signal.

As to the several definitions of block signaling set forth by the American Railroad Association, that is, the telegraph block, the manual and the automatic, hardly a word was said on these subjects; moreover, the old contentious point of the distant signal even was not discussed, and, as I have said before, the discussion dwindled into an explanation of comparatively new devices for block working. The main portion of the discussion related to the Kinsman block system and to the Hall block system, Mr. Hasell contributing matter relating to his own system. I would point out, however, that my object in writing this paper and any papers, is not for the particular recommendation and particular explanation of any individual system; it is rather to put forward suggestions relating to the fundamental principles of signaling to which any system should conform.

It must be obvious to the railroads of the United States that a general system involving uniform standards is the best for their interests, and it would seem to require little reasoning, or even trouble, to arrive at certain standards which must, in spite of individual exertions, become the standards of the future; take, for instance, the question of the shape of the block signal. Can any one reasonably suggest a disk, which has only color and not position, for indication as against a semaphore arm which has position and color, if you like, though the color is not important for the day signal? The argument in favor of it, no doubt, by those who promote the disk signal, is from the fact that at night the color, which is not considered of importance in the day, is bound to be considered as the night signal, since movement and position of the semaphore arm are not available at night; but, if advantages at day time can be gained by the semaphore arm, there is no reason why an alteration should be made in favor of a disk; moreover, the majority of the railroads of the old world have used the semaphore arm for the last half century, and the trunk lines of the United States, such as the New York Central and Pennsylvania Railroads, have also adopted the semaphore arm.

The question of the shape of the signal is one affecting the engineers of trains. In these days when lines are liable to be traveled over by foreign locomotives it is desirable that a uniform and standard form of signal should be adopted so that an engineer in charge of a train, no matter on what line he may be traveling, will see the same form of outward indication for guidance.

One point that is raised for the use of a disk in lieu of a semaphore as the block signal on a passenger road is the cheapness in the manipulation, but, although this is a point which must be considered by some of the railroads, still, the little extra expense to operate a semaphore arm is not one which ought to be considered in signaling schemes for the safety of railroads.

I am not, as is, perhaps, known, in favor of automatic signaling of any description, and I consider that if the cost were carefully gone into, that is, taking the same results obtained by a manually operated plant and an automatic plant, that the balance would be in favor of the manually operated plant. In a manually operated plant the conflicting switches are generally operated from a central position and interlocked with the conflicting signals, and the expense of this installation is counted as against the operation of signals only with an automatic plant.

In looking over the particulars supplied of the Kinsman block system, it appears to involve three line wires for double track and four line wires for single track; this, in addition to track circuits, would involve a considerable expense, if expense is a consideration. Again, there is a constant current flowing in the track, the battery power being always in use. The Kinsman system, so far as I understand it, has two uses: first, as an automatic block system without the use of visual signals; and, secondly, as an auxiliary to the signals now in use. As regards the abolition of signals, utilizing the Kinsman system as a block system, I do not think it is desirable, for I think an engineer in charge of a train should have some indication to guide him in the slackening of the speed of his train instead of relying at all times upon the presence of a train or obstruction at the box in advance to automatically bring his train to a stand on every occasion where a train should be stopped. If the train should not stop on the treadle bars there would appear to be no indication to tell him when to re-start his train. On the other hand if the train should stop on the bars all he has to inform him is the noise made by the dropping away of the armature in the engine, indicating section clear. The same action relates to a misplaced switch. If a failure occurs on the locomotive, it is fatal to the correct working of the system. Should a failure of the treadle, a fracture of the wire to the treadle, or any damage to the track relay take place, collisions are possible. It would appear that if an obstruction occurs in the section ahead it should return the rear section signal to "danger" if it had been lowered, but this does not appear so from the explanations. In this system, being purely automatic, there is again the point to be considered for the interlocking of signals and switches at stations, and if no signals are used there would have to be some interlocking between the treadles, conflicting switches and locomotive. If block signals are used, then the Kinsman system would appear to be purely an addition for preventing a train running past a signal, to the signaling system now in use on, say, any of the lines in Great Britain, or the New York Central in the United States.

In justice, however, to the inventor of this system, I have to say that I have never seen it in operation, nor even a model of it, and any

objections are only gathered from the pamphlet and description contributed by Mr. Crowell. It is possible, therefore, I may be wrong in some of my conclusions as to detail defects.

Leonard's System.—This system, a description of which I read in the *Engineering News* of July 27th, 1894, appears to be practically as near as possible the Sykes Lock and Block system as used in Great Britain. The tappet attached to the lever and the notch acting as a pawl fulcrumed to the instrument operating in the notch in the said tappet are practically mechanical equivalents for similar parts doing similar duties in the Sykes Lock and Block. The starting signal lever at each section is normally locked until sanction has been given by the section in advance. After the section signal lever, say, the starting signal lever, has been worked over for the passage of a train out of the section, a bell continues to ring at that tower until the lever is replaced to the normal position. This is exactly the same as was fixed at Waterloo, London and South Western Railway, England, in 1892, in connection with all the starting signals—a buzzer, in lieu of a bell, is kept going until the advance starting signal lever is replaced to the "danger" attitude. The signalman, although he need not place his lever back, cannot get sanction from the cabin, in advance, until his lever is replaced. This again is the same as Sykes' (senior) in Great Britain.

Cancellation is allowed and a push-button is provided for that purpose. It is a one-wire system, the same as Sykes'. Short insulated lengths of rail are also provided for track-circuit purposes.

The only difference between this system and the Sykes system as used in this country (which latter is not so good as that used on the New York Central Railroad) is in the details of construction of the instrument. Two double instruments are provided in each box for single lines.

A feature of the invention is, also, by the application of a motor and accelerating gear, that the semaphore is lowered without requiring the presence of a local operator upon the unlocking of its respective lever.

I am unable to offer any opinion as to the details of the method of operation of the system mentioned by Bentley D. Hasell, M. Am. Soc. C. E., in his written communication.

A diagram is attached thereto of a suggested alteration in the outward indication of the semaphore arms to engineers. Two semaphore arms, sometimes both on one side of the post, at other times on the other side of the post, and again at other times one on each side of the post, are set down as indicating by their joint positions certain instructions to the engineer in charge of a train. I have not been able to gather the reasons why such an alteration is suggested nor the objects gained by the same, but it would appear to me to be a distinct departure, and certainly one hardly in the right direction, to mix up

two semaphore blades for one indication, one blade being on the left-hand side of the post and the other on the right-hand side.

There would appear to me to be no reason why a departure should be made from the present system of semaphore blade for home and starting signal, or advance starting signal, and the distant signal blade with forked end; these seem to fulfill, with their present mode of working, all the requirements of railway signaling, and it would appear somewhat late to endeavor to revolutionize this system by a different understanding of these arms.

Again, I may be wrong in my understanding of Mr. Hasell's views.

It is generally fully set forth, and the most made of it, that in the majority of the automatic systems of signaling, whether the several systems promoted and in use in the United States or those tried in Europe, immediately on the operation of a conflicting switch the relative signal is thrown to "danger," or when a switch is misplaced the relative signal cannot be lowered to the "safety" attitude. This may appear to many railway engineers, who have not studied signaling, to be all that is required, for it gives a kind of color to these systems as though the conflicting switches and signals were securely interlocked. Assuming, however, that an express train (for better illustration) is on its journey on a line where an automatic system of signaling is in operation, and that the signal commanding entrance to the next section is lowered to the "safety" attitude, as the train approaches the signal, the switch, which is a hand switch, is either operated by a man on the ground, or, for some reason, springs back or moves out of its correct position, the protecting signal is thrown to the "danger" attitude, but it is not to be expected that the train can stop at an emergency of that kind; should anything be coming out of a siding or shunting in the direction of the main line, the possibility is that it might go through the safety switch and on to the main line that the express is approaching on. This may or may not be a fancied case, but this much remains, that with a manual system, that is, not an automatic system, where the switches and signals are concentrated in one spot and interlocked, so long as the passenger signal is deflected to the "safety" attitude, the lever operating the conflicting switch is locked and no movement can take place out of the siding; that is to say, that the switch is not free to be moved, even although it might put the passenger arm to "danger." The passenger arm is master of the situation, and as long as it is deflected no conflicting switch movement can take place.

Of course, it would be possible to make the deflection of the passenger arm insert a bolt or some other lock into all conflicting switches that foul the line to which the passenger signal applies, but this would mean considerable expense, and, so far as I am aware, does

not form part of the automatic systems generally in use in the United States.

I make these remarks with more particular reference to the statements of Mr. Wallace, as, in view of his experiences with the signals on the Illinois Central, particularly where he says that the closing of the switch automatically would clear the signal, and, in order to prevent the opening of the switch after the train has passed into the block, the switch is provided with indicators and bells, so that after the train has passed into the block the bell begins to ring, and rings until the train has passed out of the block; this would appear to bear out my view that no direct interlocking (by bolt or blade) of the switch by the signal is in operation. It must be obvious that the ringing of a bell, while it may be a reminder, is not a preventive, and that in the rapid passage of trains past a given spot an operator may be excused for not distinguishing between bells, or even hearing them at all. However, no safety is given by this system.

One of the leading advantages claimed for these automatic systems (it should not be claimed as an advantage, for it should undoubtedly be insisted upon as an essential) is that no failures occur in the sense that the signal ever showed "clear" when it should show "danger." It would be an interesting return to see how many times the signals showed "danger" when they ought to show "clear," because in short sections on a busy line where there may be a three or four-minute service of trains, a signal showing "danger," when it ought to show "safety," means blocking the whole of the sections in the rear and thereby suspending the traffic.

I understand that, after a given time where an automatic system of signaling is in operation, the engineer of a train is allowed to pass the signal and proceed cautiously forward; therefore, the instruction to an engineer is exactly the same in a case where a signal has failed to go from "danger" to "clear," when it ought to, as in the case when the block in advance is occupied, and, therefore, the rear sectional signal should be at "danger." The human agency which the automatic system proposes to eliminate would, in cases of this kind, be a valuable acquisition to inform engineers by flag or otherwise, as to the true state of the case, the cause of the delay, blocking of the line, or nature of the accident.

I may say that I regret I cannot follow Mr. Wallace in the distinction which he draws between a disk passenger signal and a semaphore passenger signal. He mentions that at interlocking plants situated at junction points and connections, the tracks are protected by semaphore signals and derails. I gather that it is the derail which is the important question here, and that it is the desire to educate the engineer to take more notice of a semaphore, in view of the fact that if he passes it at "danger" he will be derailed, and that with regard to the disk,

it is permanently employed, so that if he does run by it, there being no derail, he will not go off the line. So far as the traveling public is concerned, it would appear that if two separate forms of the signal are to be employed, that the important one, which is the semaphore, should be employed where there is no derail, and where, if the signal is passed at "danger," an accident would occur. I, however, consider it a very doubtful practice to recommend or even countenance the use of two forms of signals on passenger roads, one of which may be permissive and the other absolute. So far as the meaning of any signal is concerned, except the distant signal, no matter what the shape may be, if in the "danger" attitude, it should command respect from the engineer, and he should be educated to have his train sufficiently under control to stop at it. Therefore, the semaphore arm, which Mr. Wallace illustrates as ensuring more respect from engineers in charge of trains in view of the possibility of a derail beyond it, should be the adopted day signal for engineers in charge of trains, as, after all, the most we want or expect from drivers is to stop at signals and obey them when at "danger."